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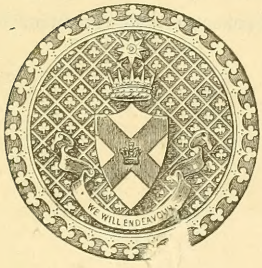

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I.—A List of Spiders Captured in the Seychelles Islands, by Professor E. Perceval Wright, M. D., F. L. S.; with Descriptio[illegible] of Species supposed to be new to Arachnologists, by J[illegible] Blackwall, F. L. S. Notes and Preface, by the Rev. O. P. Cambridge, M. A., C. M. Z. S., &c. Plates 1 & 2.

[Read, November 13, 1876.]

[The following descriptions of Seychelles Spiders were prepared by my old friend Mr. Blackwall, rather more than six years ago. Their publication has been unavoidably delayed, and a request has been made to me by Dr. E. Perceval Wright (with Mr. Blackwall's kind assent) to revise them, and to add such annotations as the progress of Araneology in the past six years might seem to require. In doing this, I have had an advantage not possessed by Mr. Blackwall; and that is, typical examples of many closely allied species for comparison with the types (kindly sent to me by Dr. Wright) from which Mr. Blackwall's descriptions were made.

Although not in accordance with the systematic arrangements now generally followed, I have, of course, not altered that which Mr. Blackwall has adopted in the present list, and which he himself established, many years ago, on strong grounds of, at least practical, conve-

nience. In order, also, not to alter nor mutilate his wonderfully lucid and minute descriptions, I have included such observations as seemed requisite, in a different type, and within brackets, chiefly at the end of the several descriptions of those species to which the observations apply.

O. P. Cambridge.

Bloxworth, Dorset,
September 19*th*, 1876.]

Tribe **OCTONOCULINA.**

Family SALTICIDÆ.

Genus Salticus, *Latr.*

Salticus Wrightii, n. sp. [Attus, Sim.]. Plate 1, fig. 1.

Length of the female (not including the spinners) $\frac{3}{10}$ths of an inch; length of the cephalothorax, $\frac{3}{20}$; breadth, $\frac{1}{10}$; breadth of the abdomen, $\frac{1}{12}$; length of an anterior leg, $\frac{5}{16}$; length of a leg of the third pair, $\frac{1}{4}$.

The minute intermediate eye of each lateral row is nearer to the anterior than to the posterior eye of the same row. The cephalothorax is large, glossy, and somewhat quadrilateral; it slopes abruptly at the base, has a broad indentation in the medial line, and is of a dark reddish-brown colour, with a broad, curved, brownish-red, transverse band near the middle, whose convexity is directed backwards, and a transverse bar of the same hue between the anterior and posterior eyes. The falces are powerful, conical, slightly prominent, divergent at the extremity, and armed with a few teeth on the inner surface. The maxillæ are strong, straight, and enlarged at the extremity, which is obliquely rounded on the inner side; and the lip is oblong, and rounded at the apex. These parts are of a reddish-brown colour, the extremity of the maxillæ and the apex of the lip having a yellowish-white hue. The sternum is oval, with slight prominences on the sides, opposite to the legs; the posterior is broader than the anterior extremity, and its colour is yellowish-white. The legs are robust, especially those of the anterior pair; they are provided with hairs, and the first and second pairs have two parallel rows of spines on the inferior surface of the tibiæ and metatarsi; the anterior legs are of a reddish-brown colour, with the exception of the tarsi, which have a brownish-yellow hue; the colour of the first, second, and third pairs is brownish-yellow, that of the sides of the femora being brown; the first pair is the longest, then the second, and the third pair is the shortest; each tarsus is terminated by two curved, minutely pectinated claws, below which there is a small scopula. The palpi are slender, of a brownish-yellow hue, and the digital joint is supplied with long hairs. The abdomen is long, subcylindrical, and tapers to the spinners, which are prominent, the superior pair being the longest; a broad yellowish-white band,

whose lateral margins are slightly sinuous, extends along the middle of the upper part; the anterior part, contiguous to the cephalothorax, and the sides, are of a dark-brown colour; a yellowish-white line passes along the latter, from the posterior half of which two streaks of the same hue are directed obliquely backwards and downwards; the under part is of a yellowish-white colour, with a short, transverse, brown bar near the spinners, which have a dark-brown hue, their bases and extremities being yellowish-white: the sexual organs are moderately developed, and of a brownish-red colour.

I have bestowed on this prettily marked Salticus the name of Professor E. Perceval Wright, who, on various occasions, has transmitted to me highly interesting collections of foreign spiders, and has most liberally permitted me to describe such species as were supposed to be unknown to arachnologists.

Salticus acutus, n. sp. [Attus, Sim.]. Plate 1, fig. 2.

Length of the female (not including the spinners) $\frac{3}{16}$ths of an inch; length of the cephalothorax, $\frac{1}{12}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{16}$; length of a leg of the third pair, $\frac{3}{16}$; length of a leg of the second pair, $\frac{1}{8}$.

The cephalothorax is convex, glossy, somewhat quadrilateral, sloping gradually towards the front, and abruptly at the base; it has a slight depression between the posterior pair of eyes, is sparingly supplied with whitish hairs, and is of a yellowish-red colour; the cephalic region is strongly tinged with brown, especially about the lateral eyes. A brown spot occurs on each side of the posterior slope, and the frontal margin is provided with long yellowish-white hairs. The minute intermediate eye of each lateral row is nearly equidistant from the eyes constituting its extremities. The falces are short, subconical, vertical, and armed with a few teeth on the inner surface; the maxillæ are straight, and enlarged and rounded at the extremity; the lip and sternum are oval, the latter being broader at the posterior than at the anterior extremity. The legs are robust, especially those of the anterior pair, and are provided with hairs and spines, two parallel rows of the latter occurring on the inferior surface of the tibiæ and metatarsi of the first and second pairs; the third pair is the longest, then the fourth, and the first pair slightly surpasses the second; each tarsus is terminated by two curved, minutely pectinated claws, below which there is a small scopula; the palpi are short, and the radial and digital joints are well supplied with pale hairs. These parts are of a brownish-yellow hue, the falces being the darkest. The abdomen is oviform, convex above, and tapers to the spinners, which are prominent; it is clothed with pale hairs, and is of a yellowish-white colour, the under part being the palest; an irregular brown band extends along each side of the upper part, and the space between these bands comprises a series of rather obscure angular and curved lines of the same hue; a narrow band, consisting of short brown streaks and spots, curves round the anterior extremity, and passes obliquely down-

wards; the sides are marked with oblique lines composed of short brown streaks, and there is a triangular spot of a similar colour directly above the coccyx; a minute brown spot is situated immediately before the spinners on the under part, and the sexual organs, which are well developed, are of a dull reddish-brown colour.

The male bears a general resemblance to the female, but differs from her in various particulars. Its cephalothorax, which is darker coloured, has a patch of hairs before the medial depression, a smaller one behind each large anterior eye, and a broad band curved from its anterior margin across the middle of the posterior slope; these patches and the band have a white hue, and there are a few long black bristles situated below the small intermediate eye of each lateral row. The large anterior eyes are of a bright green hue, and are encircled by short white hairs. The falces have some white hairs at their base, and with the base of the maxillæ and lip are of a brown-red colour. The extremity of the femora, the genua, and the tibiæ of the first and second pairs of legs are of a red-brown colour, the inferior surface being the darkest; and the third and fourth pairs are marked with annuli of the same hue. The radial joint of the palpi is smaller than the cubital, and has a pointed adophysis directed forwards from the outer side of its extremity. The digital joint is oval, hairy, convex above, and comprises in its concavity the palpal organs, which are moderately developed, not very complex in structure, with a pointed spine curved round their extremity from the inner to the outer side, and are of a reddish-brown colour. The abdomen is slender, and the irregular brown band that extends along each side of the upper part in the female is usually more or less broken into spots in the male, and the superior spinners have a brown streak on their upper surface.

Salticus activus, n. sp. [Heliophanus, C. L. Koch]. Plate 1, fig. 3.

Length of the female (not including the spinners), $\frac{1}{6}$th of an inch; length of the cephalothorax, $\frac{1}{12}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{16}$; length of a posterior leg of the second pair, $\frac{1}{12}$.

The minute intermediate eye of each lateral row is nearly equidistant from the eyes constituting its extremities. The cephalothorax is convex, glossy, somewhat quadrilateral, with a slight indentation in the middle, and is provided with short whitish hairs; it slopes gradually towards the front, abruptly at the base, and its predominant colour is red-brown; the cephalic region has a dark-brown hue, and a line of white hairs extends along each side above the lateral margin. The falces are short, subconical, vertical, and armed with one or two small teeth at the extremity; the maxillæ are straight, and enlarged and rounded at the extremity; and the lip is oval. These organs are of a red-brown colour, the falces being the darkest, and the extremities of the maxillæ and lip the palest; the sternum is oval and rather broader at the posterior than at the anterior extremity. The legs are moderately strong, provided with hairs and spines, two parallel rows of the latter occurring on the inferior surface of the tibiæ

and metatarsi of the first and second pairs; the fourth pair is the longest, then the third, and the second pair is rather shorter than the first; each tarsus is terminated by two small, curved, minutely pectinated claws, below which there is a small scopula. These parts have a brownish-yellow hue, the legs being tinged with brown at the articulation of the joints. The palpi are short, lighter coloured than the legs, and the radial and digital joints are well supplied with pale hairs. The abdomen is oviform, convex above, somewhat pointed at the spinners, which are prominent, and is clothed with pale hairs; the upper part and sides are of a brown colour, the former being spotted with yellowish-white. A yellowish-white band, which curves round the anterior extremity, and extends along the sides, projects two streaks of the same hue from its inner margin, on each side, the two posterior ones nearly forming a transverse band about a third of its length from the spinners; the under part is of a yellowish-white colour, with a transverse brown bar before the spinners; and the sexual organs, which are minute, have a dark reddish-brown hue.

The male is smaller and much darker coloured than the female. The palpi have a dark-brown hue, and the humeral joint has a pointed process near its base, on the under side, which is curved downwards; the digital joint has an oblong oval form; it is convex above, densely clothed with whitish hairs, compact at the extremity, with a concavity at the base that comprises the palpal organs, which are neither highly developed nor complex in structure, and are of a dark-brown colour.

[I feel no doubt but that this spider is the *Attus lugubris* of Vinson (Aranéides des Iles de la Réunion, &c., p. 50, Pl. x., fig. 7), and this latter species is certainly identical with the *Attus variabilis* of the same author. The examples from which Mr. Blackwall's descriptions were made have lost colour and lustre considerably, but the abdominal pattern is quite distinct in both sexes. The humeral joint of the male palpus (as noticed by Mr. Blackwall) is armed with the pointed protuberance characteristic of the genus Heliophanus.]

Salticus constrictus, n. sp. [Salticus, Sim.]. Plate 1, fig 4.

Length of an immature female, $\frac{1}{6}$th of an inch; length of the cephalothorax, $\frac{1}{12}$; breadth, $\frac{1}{24}$; breadth of the abdomen, $\frac{1}{24}$; length of a posterior leg, $\frac{1}{6}$; length of a leg of the second pair, $\frac{1}{12}$.

The cephalothorax is long, broad and quadrate in the cephalic region, immediately behind which it is constricted, and then tapers to its base; it is glossy, sparingly supplied with hairs, projects a little beyond the base of the falces, and is of a brownish-yellow colour tinged with red, particularly on the posterior half. The eyes are seated on black spots, and the minute intermediate one of each lateral row is nearly equidistant from the eyes constituting its extremities. The

falces are short, subconical, slightly prominent, and are armed with a few minute teeth on the inner surface; the maxillæ are straight, and enlarged and rounded at the extremity; the lip is longer than broad and rounded at the apex; the sternum is long and narrow, and has slight eminences on its sides, opposite to the legs. The legs are slender, provided with hairs, and have two curved claws at the extremity of each tarsus, below which there is a small scopula; the fourth pair is the longest, then the third, and the second pair is the shortest; the palpi are short, and the digital joint is somewhat enlarged at its extremity. These parts are of a yellowish-white hue, the falces and lip having a slight tinge of red, and the genua and tibiæ of the first pair of legs have a pale-brown line extending along their anterior surface. The abdomen is oviform, glossy, thinly clothed with pale hairs, and is connected with the base of the cephalothorax by a long slender pedicle; it is strongly constricted about one-third of its length from the anterior extremity, and is of a pale yellowish-brown colour, a transverse band before and after the constriction, and the branchial opercula having a brown hue.

Family LYSSOMANIDÆ.

The spiders of this family are most nearly allied to those of the family Salticidæ, but they differ from them decidedly in the form of the cephalothorax, the disposition of the eyes, the figure of the maxillæ, of the lip, and sternum, and also in the structure of the spinners, the superior pair having the spinning-tubes arranged on the inferior surface of the pointed terminal joint. These marked differences in their external organization, indicating a corresponding modification of habits and economy, have induced me to propose for their reception a family distinct from that of the Salticidæ.

Genus Lyssomanes, *Hentz.*

[Although the genus Lyssomanes (Hentz) is an exceedingly distinct and remarkable one, there appears to be nothing to warrant its separation from the Salticides, with which its general form and characters show it to be unmistakably allied. The example from which Mr. Blackwall's description is made had apparently not long cast its skin, so that its colourless condition is probably not that which belongs to the adult form.]

Lyssomanes pallens, n. sp. Plate 1, fig. 5.

Length of an immature male (not including the spinners), $\frac{1}{3}$ of an inch; length of the cephalothorax, $\frac{1}{16}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{20}$; length of a posterior leg, $\frac{1}{4}$; length of an anterior leg, $\frac{5}{24}$.

The colour of this spider is white tinged with yellow, particularly on the sides and base of the cephalothorax. The eyes are disposed on the anterior part of the cephalothorax; two, which are situated in

front, are much the largest, and are prominent, pellucid, and almost in contact; on each side of the upper part of the cephalic region three eyes are placed, in the form of an irregular triangle, on small tubercles seated on confluent black spots, the intermediate eye, constituting the vertex of an obtuse angle, being the smallest of the eight. The cephalothorax is somewhat quadrate, convex, glossy, slightly rounded on the sides and at the base, and moderately elevated in the cephalic region. The falces are small, subconical, and inclined towards the sternum, which is broad, convex, and heart-shaped; the maxillæ are short, rounded at the extremity, and inclined towards the lip, which is somewhat quadrate, being broader at the base than at the apex. The legs are slender, and provided with hairs and long spines, two parallel rows of the latter extending along the inferior surface of the tibiæ and metatarsi of the first and second pairs; each tarsus is terminated by two minute, curved claws, below which there is a small black scopula. The abdomen is long, subcylindrical, and has a few short, pale hairs distributed over its surface. The superior spinners are the longest, and their terminal joint, which is pointed, has the spinning-tubes arranged on its inferior surface. The palpi of the specimen from which the description was made were very timid, but the palpal organs were not developed, indicating that it probably had to undergo its final change of integument before it arrived at maturity; the radial was stronger than the cubital joint, and prominent in front.

Family THOMISIDÆ.

Genus Thomisus, *Walck.*

Thomisus insularis, n. sp. [Xysticus, Koch]. Plate 1, fig. 6.

Length of the female, $\frac{3}{20}$ths of an inch; length of the cephalothorax, $\frac{1}{16}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{12}$; length of an anterior leg, $\frac{3}{20}$; length of a leg of the third pair, $\frac{1}{10}$.

The eyes are disposed on the anterior part of the cephalothorax in two transverse curved rows, forming a crescent whose convexity is directed forwards; the eyes of each lateral pair are larger than the intermediate ones, and are seated on tubercles united at their bases, the anterior ones being the largest, and the intermediate eyes of the posterior row the smallest of the eight. The cephalothorax is convex, glossy, somewhat compressed before, truncated in front, rounded on the sides, abruptly depressed at the base, and has a few fine bristles directed forward from its anterior margin; its colour is red-brown, mottled with pale red and yellowish-brown; it is darkest on each side of the posterior slope, and the lateral margins are black; a broad band, which extends from the eyes along the middle to its base, is of a yellowish-white colour in the cephalic region, and is strongly tinged with red on the posterior slope, at the commencement of which it is somewhat contracted; the anterior part of the band comprises two oblong red-brown spots whose pointed anterior extremities extend to

the posterior intermediate eyes, between which there are two short confluent streaks of the same hue. The falces are short, cuneiform, vertical, and of a red-brown colour, being palest at the base, in front, where there is an irregular yellowish-white spot. The maxillæ are obliquely truncated at the extremity, on the outer side, and inclined towards the lip, which is triangular, but rounded at the apex. These parts are of a red-brown colour, their extremities having a yellowish-brown tint. The sternum is heart-shaped, glossy, and of a pale-yellow hue. The legs are provided with hairs and spines, two parallel rows of the latter occurring on the inferior surface of the tibiæ and metatarsi of the first and second pairs, and a few conspicuous ones on the anterior side of the former; they are of a pale red-brown hue, with yellowish-white annuli more or less perfectly formed, those on the base of the third and fourth pairs being much the broadest; the first and second pairs, which are longer and more robust than the third and fourth pairs, are equal in length, and the third pair is the shortest; each tarsus is terminated by two curved, minutely pectinated claws. The palpi, which are short and slender, resemble the legs in colour, and have a small curved claw at their extremity. The abdomen is oviform, moderately convex above, projecting a little over the base of the cephalothorax, and has a few short hairs distributed over its surface; it is of a whitish hue, with a large dark-brown band, freckled with minute white spots, extending along the middle of the upper part to the coccyx; this band is irregular in outline and broadest about the middle; it then tapers to its extremity, which has a tinge of red, and projects short parallel streaks from each side; a white line, which passes from the anterior part of the band along the middle, is crossed near its extremity by two short curved lines of the same hue, and is followed by two white spots, the anterior one being the larger; the band also comprises five depressed dark-brown spots; the three anterior ones describe an angle whose vertex is directed forwards, and the other two are parallel to its base; the sides are marked with dark-brown confluent spots that form oblique rows; a pale-brown band, which tapers to its extremity, extends from the yellow branchial opercula along the middle of the under part to the spinners, the superior and inferior pairs of which organs are spotted with black at the base; the sexual organs are well developed, and have a pale red-brown hue.

Genus Olios, *Walck.*

Olios validus, n. sp. [Isopeda, L. Koch]. Plate 1, fig. 7.

Length of the female, $1\frac{3}{5}$ inch; length of the cephalothorax, $\frac{7}{12}$; breadth, $\frac{9}{16}$; breadth of the abdomen, $\frac{1}{2}\frac{1}{6}$; length of a leg of the second pair, $2\frac{6}{10}$; length of a leg of the third pair, $1\frac{9}{10}$.

The eyes are disposed on the anterior part of the cephalothorax in two transverse nearly parallel rows, the anterior row, which is the shorter, being situated immediately above the frontal margin; the

four intermediate eyes form a square, and those of each lateral pair are placed obliquely and wide apart on a tubercle; the anterior lateral eyes are the largest, and the posterior intermediate ones the smallest of the eight. The cephalothorax is large, convex, glossy, slightly compressed before, truncated in front, rounded on the sides, and has an indentation in the medial line of the posterior region; it is clothed with short dull-yellowish hairs, and has a red-brown hue, the anterior part being the darkest. The falces are powerful, conical, slightly prominent, somewhat divergent at the extremity, armed with teeth on the inner surface, and have some long yellowish hairs in front; the maxillæ are strong, rounded at the extremity, and curved towards the lip, which is somewhat quadrate, being broader at the base than at the apex. These parts are of a brownish-black colour, the extremity of the maxillæ and the apex of the lip having a tinge of red; the latter and the extremity of the falces on the inner side are densely fringed with long bright-red hairs; the sternum is heart-shaped, and of a red-brown colour. The legs are long, robust, provided with hairs and strong sessile spines, and are of a red-brown colour; the second pair is the longest, then the first, and the third pair is the shortest; each tarsus is terminated by two curved, pectinated claws, and the anterior part of the tibiæ and the metatarsi and tarsi are supplied with dark-brown scopulæ on the inferior surface. The palpi resemble the legs in colour; the digital joint, which is the darkest, is supplied with numerous short hairs, and has a small, curved, pectinated claw at its extremity. The abdomen is oviform, pointed at the spinners, convex above, and projects over the base of the cephalothorax; the upper part is clothed with short hairs, some long ones of a yellowish hue being interspersed; it is of a brown colour, and has a short, transverse, yellow bar at its anterior extremity; the under part is black; a broad transverse, orange-coloured band, comprising the branchial opercula and sexual organs, occurs at its anterior extremity, and from each of the branchial stigmata a fine yellowish-white line passes nearly to the spinners. The sexual organs are moderately developed, somewhat oval in form, and of a red-brown colour.

The male is smaller than the female, and its legs are much more slender; it is rather lighter coloured also, and the extremity of its abdomen, on the under side, has also an orange hue. The radial, which is a little longer than the cubital joint of the palpi, has a long spine directed forwards from each side of its base, and projects a strong and somewhat pointed black apophysis from its extremity, on the outer side; the digtial joint has an oblong-oval form, and brown colour; it is convex and hairy externally, concave within, comprising the palpal organs, which are well developed, complex in structure, with a strong process curved round the base to the inner side, and their colour is an intermixture of very dark and light red-brown.

[The genus Olios, Walck. (Sarotes, Sund.) being found incapable of including a large number of gigantic Thomisidæ of this group, discovered

lately (especially in Australia), these spiders have been subdivided into several more or less well-marked genera by Dr. T. Thorell, and Dr. L. Koch; to one of these genera, Isopeda (L. Koch), the fine spider above described appears to belong. The genus Sarotes, Sund., now comprises a restricted group, of which the type is the widely dispersed and common species *S. regius*, Fabr. = *Olios leucosius*, Walck.].

Genus Sparassus, *Walck.*

Sparassus guttatus, n. sp. [Leiocranum, L. Koch]. Plate 1, fig. 8.

Length of an immature female, $\frac{1}{6}$th of an inch; length of the cephalothorax, $\frac{1}{16}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{16}$; length of an anterior leg, $\frac{1}{4}$; length of a leg of the third pair, $\frac{1}{6}$.

The eyes, which are seated on black spots, are disposed on the anterior part of the cephalothorax in two slightly curved, nearly parallel rows, the posterior row being rather the longer; the four intermediate eyes form a square; the two anterior ones are the largest and darkest coloured of the eight, and the two posterior ones are the smallest. The cephalothorax is convex, glossy, compressed before, rounded in front and on the sides, depressed at the anterior part, abruptly so at the base, and has an indentation in the medial line of the posterior region; it is of a brownish-yellow colour, with narrow, dark-brown lateral margins; a short line is directed backwards from each eye of the posterior row, and a fine one passes obliquely backwards from the extremity of each exterior line till it comes in contact with a medial line whose anterior extremity is the finer, and the sides are marked with spots and short streaks; these lines, streaks and spots are of a brown colour. The falces are conical, vertical, and armed with a few small teeth at their extremity; the maxillæ are short, rounded at the extremity, and slightly inclined towards the lip, which is broader than long and somewhat quadrate; and the sternum is broad, convex and heart-shaped. These parts are of a yellowish-white colour, and the falces, which are rather the darkest, have an oblong brown spot at their base, in front. The legs are slender, and do not differ greatly in length; they are provided with hairs and long sessile spines, two parallel rows of the latter extending along the inferior surface of the tibiæ and metatarsi of the first and second pairs, and are of a dull-yellowish colour, tinged with brown, the metatarsi of the posterior legs having a dark-brown annulus at their base and extremity; the first pair is rather the longest, the fourth pair slightly surpasses the second, and the third pair is the shortest; each tarsus is terminated by two curved, minutely pectinated claws, below which there is a small scopula. The palpi resemble the legs in colour, and have a slender, curved, slightly pectinated claw at their extremity. The abdomen is oviform, pointed at the spinners, moderately convex above, and projects a little over the base of the cephalothorax; it is of a

yellowish-white colour, the under part being the palest; the sides are freckled with small brown spots, and there is a series of spots of a similar hue, having an angular form and somewhat larger size, that extends along the middle of the upper part, but is not continued to its extremities; two large black spots occur on each side of the under part; the anterior ones comprise the branchial opercula, and the posterior ones, which are the largest, are pointed at their posterior extremity.

I have felt some difficulty in assigning a place to this spider in the family Thomisidæ, to which its immature state has in some measure contributed. In several particulars, and especially in the figure of its lip, it resembles certain species belonging to the genus Olios, but I have been induced by its predominant characteristics to include it, provisionally, in the genus Sparassus.

[Whatever this spider may be, it is certainly not a Sparassus, and, in spite of a very laterigrade appearance, it probably belongs to the Drassides rather than to the Thomisides. I have a very nearly allied, though distinct (and as yet undescribed), species of the genus to which it belongs, from Ceylon. Dr. Ludwig Koch, to whom I forwarded examples of the Ceylon species, says they are certainly of the family Drassides, and, in his opinion, of the genus Leiocranum, L. Koch.

It will probably be necessary to found a new genus upon these spiders, differing, as they do materially, from the typical Leiocranum, into which genus I cannot at all fit them. In giving the above opinion I am supported by the difficulty felt by Mr. Blackwall in regard to assigning this spider a place in the family Thomisides, and by his placing it, provisionally only, in the genus Sparassus—(see the remarks at the end of his description).]

Family DRASSIDÆ.

Genus Clubiona, *Latr.*

Clubiona nigromaculosa, n. sp. Plate 2, fig. 9.

Length of an immature female, $\frac{5}{24}$ths of an inch; length of the cephalothorax, $\frac{1}{10}$; breadth, $\frac{1}{12}$; breadth of the abdomen, $\frac{1}{16}$; length of a posterior leg, $\frac{5}{16}$; length of a leg of the third pair, $\frac{1}{5}$.

The abdomen is oviform, pointed at the spinners, which are prominent, thinly clothed with white hairs, moderately convex above, projecting over the base of the cephalothorax, and is of a pale-yellowish colour; a series of six small black spots, disposed in pairs and almost contiguous, extends from the anterior extremity of the upper part along the middle nearly half of its length, and is followed by a series of eight very minute spots of the same hue, also disposed in pairs, but

separated by distinct intervals; these series are comprised between two rows of black spots, which converge towards the spinners, two of them, on each side, being confluent with those of ultimate and penultimate pairs of the intermediate series of minute spots; a few very minute black spots also occur on the posterior half of each side. The eyes are seated on black spots, and form two transverse rows on the anterior part of the cephalothorax; the anterior row, which is the shorter and straight, is situated immediately above the frontal margin; the posterior row is slightly curved, having its convexity directed upwards, and the interval between the intermediate eyes is greater than that which separated them from the lateral eyes of the same row; the four intermediate eyes describe a trapezoid, the two anterior ones, which form its shortest side, being rather the largest of the eight. The cephalothorax is oval, rounded in front and on the sides, convex, glossy, with a very slight narrow indentation in the medial line of the posterior part; it is of a dull-yellow colour, with a fine, irregular, brown line on each side of the cephalic region. The falces are conical, rather prominent, and armed with a few small teeth on the inner surface; the maxillæ are enlarged and somewhat divergent at the extremity; the lip is oblong, and broader at the base than at the apex, which is rounded; the sternum is oval, with small prominences on the sides, opposite to the legs. The legs are long, and provided with hairs and sessile spines, dark-coloured hair-like papillæ occurring on the inferior surface of the metatarsi and tarsi of the first and second pairs; the fourth pair is the longest, then the second, and the third pair is the shortest; each tarsus is terminated by two curved, pectinated claws, below which there is a small scopula; the palpi are short, and the digital joint is well supplied with hairs, which give it the appearance of being somewhat enlarged, particularly at the extremity. These parts have a pale-yellowish hue, the cephalothorax being rather the darkest.

Family CINIFLONIDÆ.

Genus Orithyia, *Blackw.* [Uloborus, *Walck.*]

Orithyia Williamsii.

Orithyia Williamsii, *Blackw.*, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. ii., p. 331; vol. viii., p. 443, and vol. xviii., p. 453.

Orithyia luteola.

Orithyia luteola, *Blackw.*, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. xvi., p. 89.

Orithyia gnava.

Orithyia gnava (female), *Blackw.*, *Ann. and Mag. of Nat. Hist.*, ser. 3, vol. xvi., p. 90.

The male of this species, which seems to have escaped the observation of arachnologists, is not so robust as the female, but its legs are

longer; it is also rather darker coloured, and the protuberance on which the intermediate eyes of the anterior row are seated is more prominent. The palpi are short; the radial is stronger than the cubital joint, and the digital joint is oval, pointed at its extremity, convex and hairy externally, concave within, comprising the palpal organs, which are highly developed, prominent, not very complex in structure, and of a brownish-yellow colour. The convex sides of the digital joints are directed towards each other.

Family THERIDIIDÆ.

Genus THERIDION, *Walck.*

THERIDION PLACENS, n. sp. Plate 2, fig. 10.

Length of the female, $\frac{3}{20}$ths of an inch; length of the cephalothorax, $\frac{1}{16}$; breadth, $\frac{1}{20}$; breadth of the abdomen, $\frac{1}{12}$; length of an anterior leg, $\frac{1}{4}$; length of a leg of the third pair, $\frac{1}{8}$.

The cephalothorax is convex, glossy, compressed before, rounded in front and on the sides, and has an indentation in the medial line of the posterior region; the falces are conical and vertical; the maxillæ are obliquely truncated at the extremity, on the outer side, and inclined towards the lip, which is semicircular; the sternum is heart-shaped. The legs are long, and provided with hairs; the first pair is the longest, then the third, and the fourth pair is the shortest; each tarsus is terminated by three claws; the two superior ones are curved, and slightly pectinated, and the inferior one is inflected near its base; the palpi are slender and have a curved minutely pectinated claw at their extremity. These parts are of a pale-yellowish colour. The eyes are disposed on the anterior part of the cephalothorax in two transverse rows; the four intermediate ones form a square, the anterior ones, which are seated on a small protuberance, being the largest and darkest of the eight; the eyes of each lateral pair are placed on a minute tubercle, and are contiguous. The abdomen is oviform, convex above, and projects over the base of the cephalothorax; it is of a yellowish-brown colour, the under part being the palest, with an irregular line composed of white spots extending along each side of the middle of the upper part; the sexual organs, which are moderately developed, have in connexion with them a triangular process directed backwards, and are of a yellowish-red colour.

The male is rather smaller and darker coloured than the female. The radial joint of its palpi is stronger than the cubital joint; the digital joint is oval, convex and hairy externally, concave within, comprising the palpal organs, which are well developed, rather complex in structure, with a fine, black, slightly-curved, pointed spine on the lower side, which is directed forwards. The convex sides of the digital joints are directed towards each other.

Immature individuals of this species are darker coloured than adult females.

Theridion leve, n. sp.

Length of an immature female, $\frac{1}{12}$th of an inch; length of the cephalothorax, $\frac{1}{24}$; breadth, $\frac{1}{30}$; breadth of the abdomen, $\frac{1}{24}$; length of an anterior leg, $\frac{1}{8}$; length of a leg of the third pair, $\frac{1}{12}$.

The eyes are seated on black spots on the anterior part of the cephalothorax; the four intermediate ones form a square, the two anterior ones, which are placed on a small protuberance, being the largest of the eight; the eyes of each lateral pair are seated on a minute tubercle, and are near to each other, but not in contact. The cephalothorax is slightly compressed before, rounded in front, and on the sides convex, glossy, and has a slight indentation in the medial line of the posterior region; it is of a yellowish-white colour, a brown band extending from each lateral pair of eyes nearly to its base. The falces are conical, vertical, and have a brownish-yellow hue. The maxillæ are obliquely truncated at the extremity on the outer side, and inclined towards the lip, which is short and pointed at the apex. These organs have a pale-yellowish hue, the former being tinged with brown on the outer side. The sternum is heart-shaped, convex, glossy, and of a dull yellow colour, with brownish-black lateral margins. The legs are slender, supplied with short hairs, and are of a pale yellowish-brown hue, marked obscurely with soot-colour at the articulation of the joints; the first pair is the longest, then the second, and the third pair is the shortest. The palpi are short, without soot-coloured marks, and are terminated by a small curved claw. The abdomen is oviform, convex above, projects over the base of the cephalothorax, and is of a dull-yellowish colour, freckled with white; a pale brown dentated band extends from the anterior extremity of the upper part, along the middle, about two-thirds of its length, and is followed by three soot-coloured lines that meet at the coccyx, the intermediate one being composed of small spots; the spinners have a brownish-black hue, and the outer side of the branchial opercula is soot-coloured.

Genus Argynodes, *Simon.*

Argynodes rostrata, n. sp. Plate 2, fig. 11.

Length of the male, from the anterior part of the cephalothorax to the summit of the abdominal cone, $\frac{1}{12}$ of an inch; length of the cephalothorax, $\frac{1}{20}$; breadth, $\frac{1}{30}$; breadth of the abdomen, $\frac{1}{24}$; length of an anterior leg, $\frac{1}{5}$; length of a leg of the third pair, $\frac{1}{12}$.

The abdomen rises from its anterior extremity, which projects a little over the base of the cephalothorax, into a large obtuse cone greatly elevated above the spinners; the upper part has a brilliant silvery-white colour, with a brownish-black band extending along the middle to the summit of the abdominal cone; the sides, posterior face of the cone, and under part are of a brownish-black colour, the last having a tinge of red; a white point is projected from the upper part on each side; a line of the same hue, bifid at its superior extremity, extends along each side of the posterior face of the cone, and two small

white spots are placed transversely, immediately before the spinners, on the under side; these points, streaks, and spots have a brilliant silvery lustre. The cephalothorax is oval, moderately convex, glossy, with a slight indentation in the medial line of the posterior part, and a pointed conical prominence in the cephalic region, which has a process in front directed obliquely forwards and upwards, whose obtuse extremity is provided with hairs; it is of a red-brown colour, the fine lateral margins and the summit of the cone being much the darkest. The falces are conical, vertical, and armed with a few teeth on the inner surface; the maxillæ are somewhat enlarged at the extremity, and slightly inclined towards the lip. These organs are of a red-brown colour, the maxillæ being rather the darker. The lip is semicircular, and prominent at the apex, and the sternum is heart-shaped, convex, and glossy. These parts have a brownish-black hue. The eyes are seated on the cephalic cone; the four intermediate ones nearly form a square; the two anterior ones, which are the largest of the eight, are situated on the summit of the cone, in front, and the two posterior ones a little below the summit; the eyes of each lateral pair are placed on a minute tubercle nearer to its base, and are contiguous. The legs are slender, provided with short hairs, and have a pale yellowish-brown hue; the first pair is the longest, then the second, and the third pair is the shortest. The palpi resemble the legs in colour, with the exception of the digital joint, which has a dark-brown hue, tinged with red; the cubital is larger than the radial joint, and the digital joint is oval, convex, and hairy externally, concave within, compressing the palpal organs, which are highly developed, complex in structure, prominent at the extremity on the outer side, and are of a red-brown colour.

[This spider is exceedingly closely allied to *Argyrodes epeiræ*, Sim., but may be distinguished without difficulty by the more projecting (or less vertical) direction of the characteristic process in front of the upper part of the caput. In general form, colours, and markings the two species are remarkably similar; and probably the economy of the Seychelles species is the same as that of *A. epeiræ*, since the spider (*Cyrtophora* (*Epeira*) *opuntiæ*, Duf.) in whose webs the latter is found appears to be also found in the Seychelles Islands.]

Family EPEIRIDÆ.

Genus Epeira, *Walck.*

Epeira obscura, n. sp. [Epeira nocturna, Vins.]

Length of the female, $\frac{2}{3}$ of an inch; length of the cephalothorax, $\frac{1}{3}$; breadth, $\frac{1}{6}$; breadth of the abdomen, $\frac{1}{2}$. The first pair of legs is the longest, then the second, and the third pair is the shortest; but as

these limbs were mutilated, their absolute length could not be determined with accuracy.

The cephalothorax is compressed before, rounded in front and on the sides, convex, depressed at the base, with an indentation on the medial line of the posterior region; it is thinly clothed with short whitish hairs, and is of a reddish-yellow colour. The eyes are disposed on the anterior part of the cephalothorax in two transverse rows; the four intermediate ones are seated on a prominence, and nearly form a square, the two anterior ones, which are wider apart than the posterior ones, being the largest of the eight; the eyes of each lateral pair are placed obliquely on a tubercle, and are near to each other, but not in contact. The falces are powerful, conical, vertical, and armed with teeth on the inner surface; the maxillæ are short, straight, and enlarged and rounded at the extremity. These organs are of a dull-yellowish hue, tinged with soot-colour on the inner surface. The lip, which is semicircular, is of a reddish-brown colour at the base, that of the margin and apex being yellow. The sternum is heart-shaped, with small eminences on the sides, opposite to the legs; it has a brownish-yellow hue, the medial line being the palest. The legs are provided with hairs, and have a brownish-yellow hue, with reddish-brown annuli. The palpi resemble the legs in colour, and are terminated by a curved, pectinated claw. The abdomen is broad, triangular, somewhat depressed, and projects over the base of the cephalothorax; it is sparingly supplied with short white hairs, and has on the upper part a large, dentated, dark-brown mark, that tapers to the spinners; it is obscurely mottled with dull yellow, and is barred transversely with dark brown above the coccyx; the anterior part comprises a dark-brown band that extends more than a third of its length, and is triangular at its anterior, and obtuse at its posterior extremity; brown lines pass obliquely from the lateral margins of the dark-brown mark to the upper part of the sides, which, with the under part, are of a brownish-yellow hue, streaked and freckled with brown; the middle of the under part is brown, tinged with dull-yellow in the medial line, and has a pale-yellow line on each side, which is enlarged and curved inwards at its posterior extremity. The sexual organs are well developed, of a red-brown colour, and project from their anterior margin a pointed, prominent process, directed backwards, which is somewhat depressed and hollowed on the upper side at its extremity.

[This spider, *Epeira obscura*, is, without doubt, the *E. nocturna*, Vinson. (Aranéides des Iles de la Réunion, &c., Pl. 4, fig. 3).]

Epeira Morelii.

Epeira Morelii, *Vinson, Aranéides des Iles de la Réunion, Maurice et Madagascar*, p. 166, Pl. iv., fig. iv.

Length of the female, $\frac{5}{16}$ of an inch; length of the cephalothorax, $\frac{1}{8}$; breadth, $\frac{1}{12}$; breadth of the abdomen, $\frac{1}{8}$; length of an anterior leg, $\frac{1}{2}$; length of a leg of the third pair, $\frac{1}{4}$.

The figure and description of this handsome species given by M. Vinson are those of a young male, whose palpal organs were not developed, and which probably had to undergo its final ecdysis before it arrived at maturity.

As the female, though larger than the male, resembles it in colour, I shall here briefly offer a few remarks upon it relative to such particulars as have been omitted by M. Vinson. The eyes are seated on black spots, and the posterior ones of the lateral pairs are the smallest of the eight. The maxillæ are enlarged and somewhat rounded at the extremity, and of a brownish-yellow colour. The lip is semicircular, and slightly pointed at the apex; and the sternum is heart-shaped, with eminences on the side, opposite to the legs. These parts have a brown colour; the base of the lip, which is the darkest, is tinged with red, and its apex has a brownish-yellow hue; a yellowish-white line, that tapers to its extremity, extends along the middle of the sternum. The first and second pairs of legs are marked with brown at the extremity of the joints, on the under side, and the fourth pair is longer than the second. The abdomen has a brown band, streaked longitudinally with dull yellow, extending along each side, and the yellowish-white medial band on the upper part comprises an obscure, pale-brown, longitudinal line: the branchial opercula have a brown hue, and there is in connexion with the sexual organs a prominent curved process, directed backwards, which is of a red-brown colour, its extremity being much the darkest.

Epeira opuntiæ [Cyrtophora, Sim.]

Epeira opuntiæ, *Dufour, Descript. de six Aran. nouv., Ann. génér. des sc. phys.*, tom. iv., p. 359, Pl. 69, fig. 3.

Epeira cognata, n. sp. [Argyrodes, Sim. Family Theridiidae.] Plate 2, fig. 12.

Length of the female, from the anterior part of the cephalothorax to the summit of the abdominal cone, $\frac{1}{5}$ of an inch; length of the cephalothorax, $\frac{1}{12}$; breadth, $\frac{1}{16}$; breadth of the abdomen, $\frac{1}{12}$; length of an anterior leg, $\frac{1}{2}$; length of a leg of the third pair, $\frac{1}{3}$.

The abdomen has a large conical protuberance situated near the middle of the upper part, high above the spinners, which has an obtuse prominence on each side of its extremity; it is broader in the middle than at the anterior part, which projects a little over the base of the cephalothorax; a black band, bordered by a white line, extends along the middle of the upper part to the base of the conical protuberance, which is black in front, with a white spot on each side, and of a yellowish-white colour, mingled with black, in its posterior region, the apices of its terminal prominences having a yellowish-white hue, and there are a few white spots at the base of the spinners; the sides have a triangular form, and their colour is black, with pale reddish and yellowish-brown intermixed, an angular whitish mark, whose lower limb is the longer, and whose vertex is directed backwards and downwards, being situated at the extremity of each; the

under part has a dull reddish-brown hue, obscurely spotted with yellowish-white, that of the branchial opercula being brown. The sexual organs are highly developed, very prominent, much enlarged at the extremity, which has a convexity on each side,[1] and their colour is dark red-brown. The cephalothorax is somewhat oval, slightly compressed before, moderately rounded on the sides, convex, glossy, with a large transverse indentation in the medial line, and is of a dark red-brown colour, the medial region being the palest. The falces are conical, rather prominent, and armed with a few teeth on the inner surface: the maxillæ are obliquely truncated at the extremity, on the outer side, and slightly inclined towards the lip, which is semicircular, but somewhat pointed at the apex; and the sternum is oblong heart-shaped, with small eminences on the sides, opposite to the legs. These parts have a yellowish-brown colour, the falces being the darkest. The eyes are disposed on the anterior part of the cephalothorax in two transverse rows, high above the frontal margin; the four intermediate ones form a square, the anterior ones, which are seated on a small prominence, being the largest and darkest coloured of the eight; the eyes of each lateral pair are seated on a minute tubercle, and are contiguous. The legs are long, slender, provided with a few hairs, and are of a yellowish-brown hue, with red-brown annuli; the first pair is the longest, then the second, and the third pair is the shortest; each tarsus is terminated by claws of the usual number and structure. The palpi are short, of a yellowish-white colour, with the exception of the radial and digital joints, which have a dark-brown hue, and the latter has a slender, curved claw at its extremity.

The male is smaller and darker coloured than the female, but its legs are longer, an anterior one measuring $\frac{7}{12}$ of an inch; the large conical protuberance is more erect, the annuli on the legs are scarcely perceptible, except at the joints, and in the space surrounded by the eyes there is a cone directed obliquely forwards, which is surmounted by a few hairs. The design formed on the abdomen by the distribution of its colours is similar in both sexes. The humeral, radial, and digital joints of the palpi are of a dark-brown colour, tinged with red, and that of the cubital joint is yellowish-brown; the radial joint is produced at its extremity, on the outer side; the digital joint is oval, convex, and hairy externally, concave within, comprising the palpal organs, which are well developed, complex in structure, and of a red-brown colour. The convex side of the digital joints are directed towards each other.

[This spider is undoubtedly an Argyrodes, and very closely allied to *A. Syriaca* (Camb.),[2] which it resembles in the very characteristic

[1] That on the left side of the specimen described appeared to be abnormal in form.

[2] Spiders of Palestine and Syria, "Proceedings Zoological Society," 187?, p. 279, pl. xiii., fig. 10.

conical prominence at the apex of the caput in the male; the larger size, however, of the spider, and a considerable difference in the form of the abdomen, together with other distinctions of colours, markings, and palpal structure will make the male easily distinguishable, while the very remarkable development of the epigyne of the female is totally unlike that of the female of *E. Syriaca*. The abnormal development of one side of this sexual appendage, mentioned in Mr. Blackwall's note, is only apparent, being evidently caused by the accidental adhesion of a small particle of resinous matter, the colour of which happens to resemble nearly that of the appendage in question.]

Genus Nephila, *Leach*.

Nephila inaurata.

Nephila inaurata, *Walckenaer*, *Hist. Nat. des Insect. Apt.*, tom. ii., p. 94.

Nephila plumipes. Plate 2, fig. 13.

Nephila plumipes, *Koch*, *Die Arachn.*, bd. vi., p. 138, tab. 213, fig. 529. *Walckenaer*, *Hist. Nat. des Insect. Apt.*, tom. ii., p. 99.

Length of the male, $\frac{7}{32}$ of an inch; length of the cephalothorax, $\frac{9}{160}$; breadth, $\frac{1}{12}$: breadth of the abdomen, $\frac{1}{15}$; length of an anterior leg, $\frac{5}{8}$; length of a leg of the third pair, $\frac{1}{4}$.

The eyes are seated on black spots on the anterior part of the cephalothorax; the four intermediate ones nearly form a square, the anterior ones, which are rather wider apart than the posterior ones, and are placed on a small protuberance, being the largest of the eight; the eyes of each lateral pair are seated on a tubercle, and are near to each other, but not in contact. The cephalothorax is convex, glossy, compressed before, rounded in front and on the sides, with a broad indentation in the medial line of the posterior region; it is of a dull-yellow colour, with a brown patch on each side of the thorax. The falces are conical, vertical, armed with one or two small teeth on the inner surface, and are of a dull-yellow colour. The maxillæ are enlarged and rounded at the extremity, and slightly inclined towards the lip, which is triangular. These parts are of a brownish-yellow colour, the latter having a dark-brown hue on each side of its base. The sternum is heart-shaped, with small eminences on the sides, opposite to the legs, and is of a dark-brown colour, a yellowish-white line, which tapers to its extremity, extending along the middle. The legs are long, slender, provided with hairs and some long spines, and are of a brownish-yellow colour; the first pair is the longest, then the second, and the third pair is the shortest. The palpi are short, and of a pale-yellow hue, that of the digital joint being brown; the radial is slightly larger than the cubital joint, and the digital joint is oval, convex, and hairy externally, concave within, comprising the palpal

organs, which are highly developed, sub-globose, glossy, with a long, slender, moderately curved process at their extremity, whose pointed termination is slightly recurved, and are of a dark-brown colour. The abdomen is subcylindrical, rather broader at the anterior than at the posterior extremity, which is rounded, and projects a little beyond the spinners; a broad, irregular, olive-brown band extends along the middle of the upper part, and comprises some pale-yellow spots, six, which are minute, being disposed in pairs immediately above the spinners; a pale-yellow band curves round the anterior extremity, and passes, with some interruptions, along each side of the medial band; the sides are of an olive-brown colour, marked with irregular spots and streaks of a yellow hue, and a brown olive-brown band, bounded laterally by a white line, extends along the middle of the under part; the colour of the branchial opercula is dark-brown.

It will be perceived that I have felt some hesitation in announcing this Nephila, which seems to be unknown to arachnologists, as the male of *N. plumipes*, to which it appears to approximate more nearly than to any other species that I am acquainted with.

[I have carefully compared the example from which Mr. Blackwall's description is made with several undoubted examples of the male of *N. plumipes* received from the Brazils, and can find no specific difference whatever. This sex is described and figured (the figure is very imperfect) by Dr. B. S. Wilder, in the "Proceedings of the Boston Society of Natural History" for October, 1865.]

Genus Tetragnatha, *Latr.*

Tetragnatha minax, n. sp. Plate 2, fig.14.

Length of the male (not including the falces), $\frac{7}{16}$ of an inch; length of a falx, $\frac{1}{8}$; length of the cephalothorax, $\frac{1}{2}$; breadth, $\frac{1}{12}$; breadth of the abdomen, $\frac{1}{16}$; length of an anterior leg, $1\frac{1}{4}$; length of a leg of the third pair, $\frac{2}{3}$.

The eyes are seated on black spots, and are disposed on the anterior part of the cephalothorax in two transverse, nearly parallel rows; the four intermediate ones describe a square, the anterior ones, which are placed on a small protuberance, being the largest, and the anterior eye of each lateral pair the smallest of the eight. The cephalothorax is long, moderately convex, glossy, compressed before, rounded in front, slightly so on the sides, has an indentation in the medial line of the posterior region, and is sparingly supplied with short pale hairs; the falces are very long and prominent, widely divergent, narrower at the base than at the extremity, and armed with a long, slightly curved, reddish-brown fang, a curved, pointed process directed forwards near the extremity of the upper part, towards the inner side, and a row of teeth on each side of the groove occupied by the fang when in a state of repose; the superior row comprises twelve teeth, the anterior one being the largest, and the

inferior row consists of about sixteen teeth. The lip is semicircular and prominent at the apex; the maxillæ are long, straight, and enlarged at the extremity, which is rounded on the inner side, and angular and prominent on the outer side; the sternum is heart-shaped, with small eminences on the sides, opposite to the legs; the legs are very long, slender, and provided with hairs and spines; the first pair is the longest, then the second, and the third pair is much the shortest; each tarsus is terminated by claws of the usual number and structure. These parts are of a pale, dull-yellow colour; the inner margin of the maxillæ is soot-coloured, and the base of the lip has a red-brown hue. The palpi are long, slender, and of a yellowish-white colour; the radial is longer than the cubital joint and clavate; the digital joint consists of two narrow, membraneous parts clothed with hairs externally, one of which is much longer than the other; with the base of these parts the palpal organs are connected; they are moderately developed, glossy, sub-globose, and terminate in a prominent, curved spine, enveloped in membrane, which is recurved and somewhat enlarged at its extremity, and they are of a pale red-brown colour. The abdomen is long, subcylindrical, and tapers to its extremity, which projects a little beyond the spinners; it is of a dull-yellowish colour reticulated with brown lines; a ramified brown line extends along the middle of the upper part, and a longitudinal band of the same hue, freckled with minute yellowish-white spots, and bounded laterally by lines composed of numerous similar spots, occurs in the middle of the under part; the branchial opercula have a yellowish-brown hue, and there are a few white spots about the base of the spinners.

The immature female is rather darker coloured than the adult male.

Tetragnatha Thorellii, n. sp. [Meta, Koch]. Plate 2, fig. 15.

Length of the female, $\frac{1}{4}$th of an inch; length of the cephalothorax, $\frac{1}{10}$; breadth, $\frac{1}{12}$; breadth of the abdomen, $\frac{1}{10}$; length of an anterior leg, $\frac{2}{3}$; length of a leg of the third pair, $\frac{1}{2}$.

The abdomen is robust, subcylindrical, projects a little over the base of the cephalothorax, and curves abruptly downwards at its posterior extremity; the upper part and the superior region of the sides are of a bright silvery-white colour reticulated with fine brown lines, the latter having a slight golden tinge; a pale-brown ramified band extends along the middle of the former to the commencement of the posterior curve, and on each side of the curve there is a series of black spots that diminish in size as they approach the spinners; a broad brown band, palest in the medial line, whose upper margin is irregular, occupies the inferior region of the sides; the under part has a longitudinal brown band in the middle, comprising a dull-yellowish line, and is bounded laterally by a pale-brown line spotted with minute silvery spots; the branchial opercula have a brownish-yellow colour, and that of the sexual organs, which are moderately developed, is dark reddish-brown. The cephalothorax is compressed before,

rounded in front and on the sides, convex, glossy, with a large indentation in the medial line of the posterior region, and is of a brownish-yellow colour. The eyes are seated on black spots, and are disposed in two transverse rows on the anterior part of the cephalothorax; the four intermediate ones form a square; the two anterior ones, which are rather the largest of the eight, and seated on a slight protuberance, being situated immediately above the frontal margin; the eyes of each lateral pair are placed obliquely on a small tubercle, and are contiguous. The falces are powerful, very convex in front, vertical, and armed with teeth on the inner surface; the maxillæ are straight, and increase in breadth from the base to the extremity, which is angular and prominent on the outer side. These parts have a brownish-yellow hue, the latter being the darker, particularly on the inner side. The lip is semicircular, and of a red-brown colour, the apex being rather the palest; and the sternum is heart-shaped, with prominences on the sides, opposite to the legs, and has a yellowish-brown hue. The legs are long, slender, provided with hairs and a few fine spines, and are of a dark-brown colour, with the exception of the coxæ, femora, and genual joints, which have a yellowish-brown hue; the first pair is the longest, then the second, and the third pair is the shortest; each tarsus is terminated by claws of the usual number and structure. The palpi, which are slender, resemble the legs in colour, and have a slightly curved, minutely pectinated claw at their extremity.

With the Tetragnatha described above, which belongs to the family Coadunatæ of Walckenaer, I have associated the name of Professor T. Thorell, Ph. D., whose important works on arachnology should be carefully perused by all students of that department of zoology.

[This species is exceedingly closely allied to *Meta decorata* (India), and more nearly still to *M. quinquelineata*, Keys. (Bogota, South America); it is also nearly allied to *M. argentata*, Camb., and *M. culta*, Camb., Ceylon. All these species have been described as belonging to the genus Tetragnatha.]

PLATE 1.

Illustrative of a Paper by Mr. John Blackwall and Rev. O. P. Cambridge "On a List of Spiders Captured in the Seychelles Islands by Professor E. Perceval Wright."

Vide Proceedings R. I. Acad., Vol. 3, Ser. 2, p. 1.

Fig. 1. *Salticus Wrightii.* Bl., ♀. 1*a*, profile, without legs; 1*b*, genital aperture.

2. ,, *acutus.* Bl., ♂. 2*a*, profile, without legs; 2*b*, genital aperture of ♀; 2*c*, palpus of ♂.

3. ,, *activus.* Bl., ♂. 3*a*, profile, without legs; 3*b*, palpus.

4. ,, *constrictus.* Bl., ♀. 4*a*, profile, without legs.

5. *Lyssomanes pallens.* Bl., ♀. 5*a*, profile, without legs; 5*b*, upper side of forepart of cephalo-thorax, showing the relative size and position of the eyes.

6. *Thomisus insularis.* Bl., ♀. 6*a*, profile, without legs; 6*b*, upper side of forepart of cephalo-thorax, showing the relative size and position of the eyes.

7. *Olios validus.* Bl., ♂. 7*a*, forepart of upper side of cephalo-thorax, showing the relative size and position of the eyes; 7*b*, palpus of ♂; 7*c*, profile of ♂, without legs; 7*d*, genital aperture of ♀.

PLATE 2.

Illustrative of a Paper by Mr. John Blackwall and Rev. O. P. Cambridge "On a List of Spiders Captured in the Seychelles Islands by Professor E. Perceval Wright."

Vide Proceedings R. I. Acad., Vol. 3, Ser. 2, p. 1.

Fig. 8.* *Sparassus guttatus.* Bl., ♀. 8*a*, profile, without legs; 8*b*, forepart of cephalo-thorax, showing the relative size and position of the eyes; 8*c*, maxillæ and labium.

9. *Clubiona nigromaculosa.* Bl., ♀. 9*a*, profile, without legs.

10. *Theridion placens.* Bl., ♂. 10*a*, palpus; 10*b*, profile, without legs.

11. *Argyrodes rostrata.* Bl., ♂. 11*a*, profile, without legs; 11*b*, palpus.

12. *Epeira cognata.* Bl., ♂. 12*a*, profile, without legs; 12*b*, palpus; 12*c*, genital aperture of ♀; 12*d*, ditto, from below.

13. *Nephila plumipes.* C. Koch., ♂. 13*a*, palpus.

14. *Tetragnatha minax.* Bl., ♂. 14*a*, one of the falces; 14*b*, forepart of cephalo-thorax, showing the relative size and position of the eyes; 14*c*, palpus.

15. *Tetragnatha Thorellii.* Bl., ♀. 15*a*, profile, without legs; 15*b*, genital aperture.

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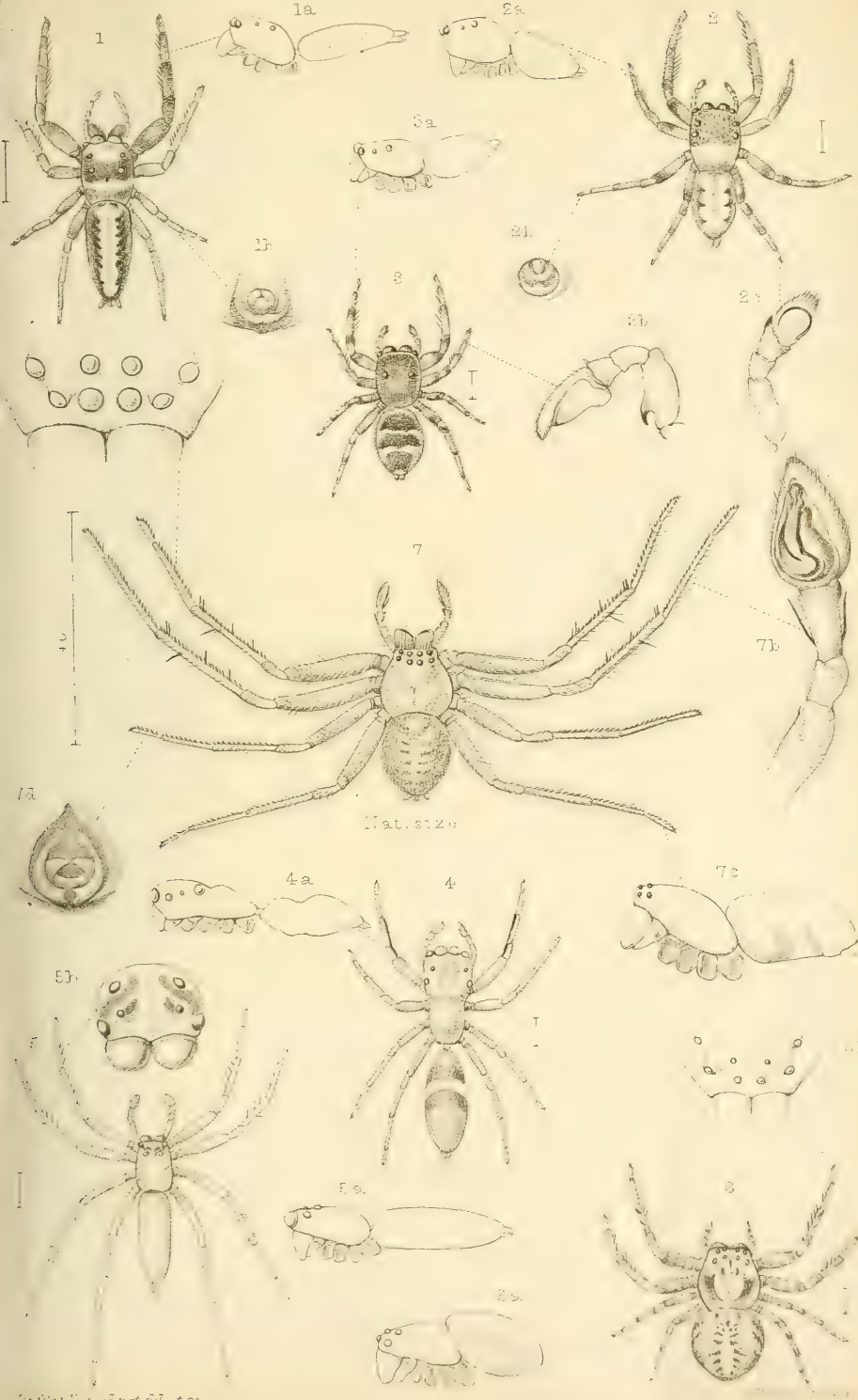
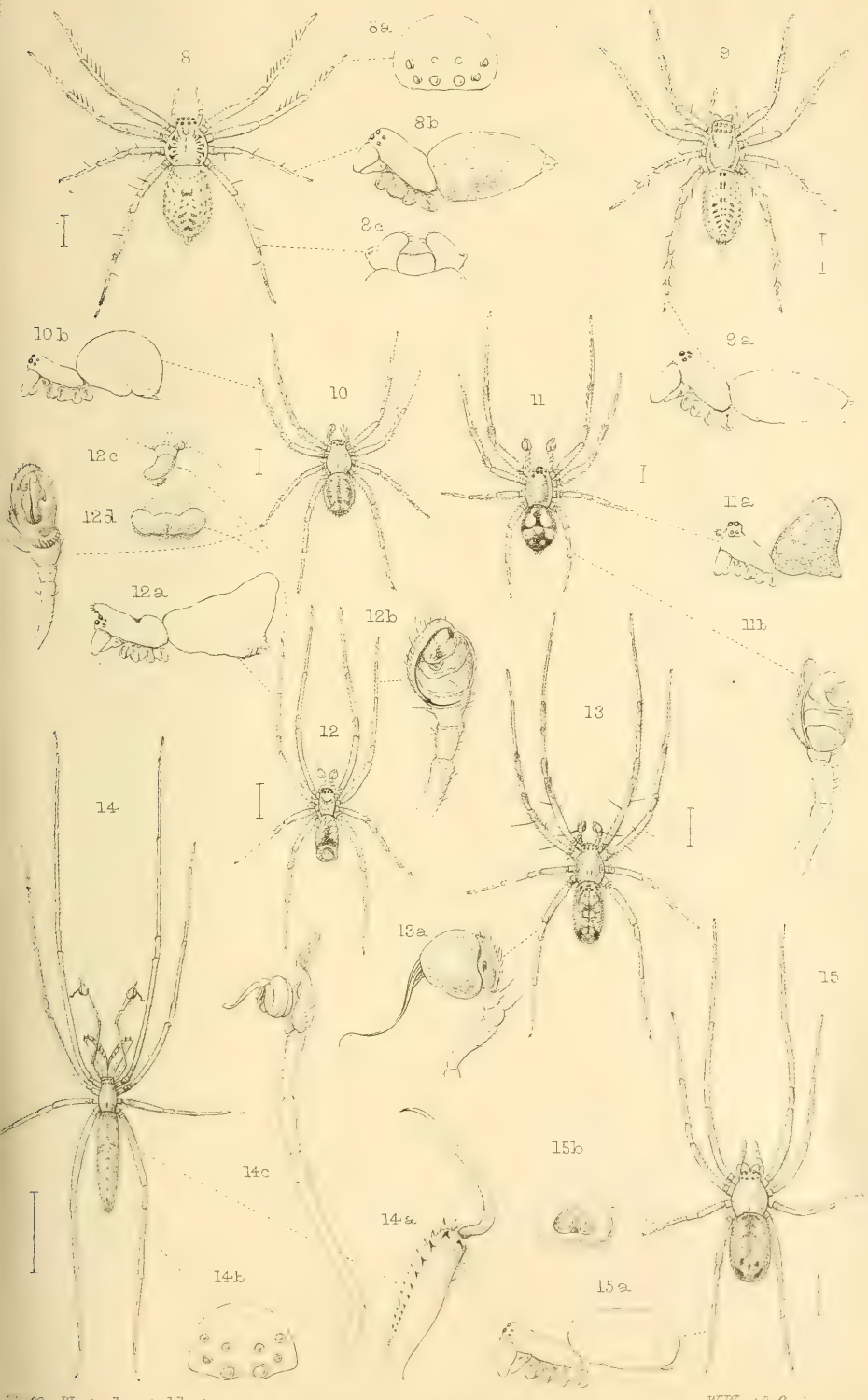
* This figure is referred to by mistake, in the description of the Spider, as in Pl. 1.



Seychelles Spiders.



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Hyptiotes Spiders

II.—Myology of the Cheetah, or Hunting Leopard of India (Felis Jubata). By F. Ogilby Ross, Student in Medicine, of Trinity College, Dublin.

[Read, November 30, 1876.]

The following facts, relative to the myology of the Cheetah, are founded on the examination of a specimen which Professors Macalister and Haughton kindly allowed me to dissect.

The animal, a fine male, was presented by Viscount Southwell to the Zoological Gardens, where it lived in good health since 1872.

A little more than a month ago it died in convulsions, for which no cause was discovered on *post-mortem* examination.

Before proceeding to describe its myology, a few facts relative to its history and general anatomy may not be out of place.

There are found in India two animals with spotted skins—the common panther of naturalists, and another, the hunting leopard, named after Daubenton, the Guepard (the hunting leopard), known to the ancients.

The Arabians also knew of and distinguished two animals with spotted skins, the first under the name of Nemer, the other under that of Fehd; the latter Bocchart considered identical with the lynx, Cuvier with the hunting leopard. Aristotle says its young were born blind. According to Herodotus, it inhabited Africa with the ibis. Its skin was spotted, and its natural disposition tameable, according to Eustathius.

The last two traits seem inapplicable to any but the animal called Fehd by the Arabians. Their not referring to its being used for hunting purposes is very natural, if, as Eldemiri informs us, the first person who so employed it was Chalib, the son of Wail.[1]

Dr. J. E. Gray[2] places the hunting leopards in a separate tribe, that of the Guepardina, of which the following are the chief characteristics: Head short, subglobate; face very short; neck slightly maned; legs elongate, slender, subequal; tail elongate; ears rounded; pupil round (?). Skull: face very short, convex; the processes of the frontals and intermaxillæ very short, not separating the nasals from the maxillæ; the flesh tooth of the upper jaw has no lobe, only a very slightly raised, scarcely visible keeled ridge, and is thin and compressed; the front, upper false grinder, distinct, small; orbits incomplete, moderate.

Genus, Gueparda, *Gray*. Cynælurus, *Wagner*.

Gueparda guttata.

Felis guttata, *Herm.*; *Blainv.*, *Ostéographie*, Felis: t. 4, (skeleton);

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[1] Cuvier, "Animal Kingdom," by Griffiths, Mammalia, vol. ii., p. 460.

[2] Dr. J. E. Gray's Notes on the Skulls of Cats, "Proceedings of the Zoological Society of London," 1867.

t. 9 (skull). F. jubata, *Schreb.* F. venatica, *A. Smith.* F. fearonis (?), *A. Smith.* Cynælurus sœmmeringii, *Rüppell.*

Professor Owen,[3] however, places it in the genus Felis. He says, "The os hyoides is connected to the cranium by an uninterrupted series of bones, thus connecting it with the cats. It possesses the circular pupil common to lion, tiger, leopard, and jaguar.

"In the form of the œsophagus and in the transverse rugæ of its lower half the Cheetah agrees with the lion, and in it, as in the other Feles, the œsophagus is not prolonged into the abdomen, but terminates, immediately after passing through the diaphragm, in the stomach; this organ in the Cheetah has all the peculiarities which are found in the genus Felis. The intestines also agree in character with those of that group; and the cæcum, as usual in it, is simple, having none of the convolution which is found in the dog. The liver, pancreas and spleen resemble those of the cats generally; as do also the kidneys in the arborescent form of their superficial veins—a form, however, equally common to the Viverridæ and the Felidæ, which also agree in having spiculæ on the tongue.

"The thoracic viscera of the Cheetah agree with those of the cats. The lytta or rudiment of the lingual bone, so conspicuous in the dog, is reduced in it, as in the other feline animals, to a small vestige.

"There is, as in the Feles generally, no bone of the penis; and the glans, as usual in them, has retroverted papillæ.

"The elastic ligaments of the ungual phalanges exist in the same number and position as those of the lion; they are, however, longer and more slender, their length alone occasioning the incomplete retraction of the claws, as compared with the rest of the Felidæ."

Professor Owen concludes by observing that in the circulatory, respiratory, digestive, and generative systems, the Cheetah conforms to the typical structure of the genus Felis.

Habitat: Africa, Asia, Persia.[4] From Southern and Western India, through Persia, Syria, Northern and Central Africa, to the Cape of Good Hope.[5]

Dr. Kirk[6] mentions it as occurring in the Makalalo country (not common) in his list of the Mammals of Zambesia.

The dissection was commenced towards the latter end of October. On taking off the skin, the panniculus carnosus was found to be moderately well developed in the fore part of the body, but more fully in the hinder part.

The trapezius was divided as usual into the clavicularis (corresponding to the anomalous cleido-occipital in man), and scapulares, superior and inferior.

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[3] On the Anatomy of the Cheetah, Felis Jubata, Schreb. "Proceedings of the Zoological Society of London," part i., 1833, p. 108.

[4] Gray, *loc. cit.*

[5] Wallace, "Geographical Distribution of Animals," vol. ii. p. 193.

[6] "Proceedings Zoological Society of London," 1864, p. 653.

The first of these arose from the par-occipital and posterior part of the squama, passed downwards parallel to the posterior border of the sterno-mastoid, and became continuous with the clavicular deltoid; the line of separation between the two being faintly tendinous, and marked by the insertion of cleido-mastoid. Weight = 1·20.

The scapularis superior, arising from the ligamentum nuchæ and 7th cervical spine, was inserted into the anterior border of the spine of the scapula. Just previous to its insertion it fused with the trachelo-acromialis, or omo-atlanticus of Professor Haughton. Weight of two together = 2·65.

The scapularis inferior, smaller and thinner than the preceding, arose from the upper six dorsal spines, and had also an additional slip of origin from the latissimus dorsi of the opposite side, inserted into the posterior fifth of the lower border of the spine of the scapula. Weight = 1·40.

The cleido-mastoid arose from the mastoid process, and was inserted into the tendinous clavicular line at the junction of the clavicular trapezius and clavicular deltoid. Weight = ·70.

The trachelo-acromialis, or omo-atlanticus of Professor Haughton, arising from the transverse process of the atlas, was inserted into the superior scapular portion of the trapezius.

The rhomboideus divided into three portions, major, minor, and occipital, the two latter being fused together.

The occipital arose as usual from the occiput, and soon fused with the minor, which took its origin from an aponeurosis, connected with the first six cervical spines, and also directly from the 7th cervical and 1st dorsal spines. It was inserted into the greater part of the posterior border of the scapula = 2·75. The major, much smaller, arose from the 2nd, 3rd, and 4th dorsal spines. Insertion into the inferior angle of the scapula, connected with the origin of teres major. Weight = ·90.

Both major and minor were very coarsely fibred, flabby, and, especially the former, mixed with a large quantity of firm yellowish fat, amounting almost to fatty degeneration.

The major was also more or less united with the serratus magnus, numerous fibres and masses of fat extending from one to the other.

The teres major (3·35) had an extensive origin from the internal surface of the scapula, posterior portion, and also from the aponeurosis covering the subscapularis. Insertion fleshy, about an inch broad, into the upper part of the internal surface of the humerus, being intimately connected with the internal head of the triceps.

From its extensive origin from the scapula, and the relative positions of this bone and the humerus, *i,. e.*, nearly at right angles, this muscle must be a powerful retractor, as well as internal rotator.

Teres minor (·31), small and cylindrical, with a second origin from long head of triceps. Insertion fleshy.

Latissimus dorsi (12·36) took an extensive origin from the 3rd–12th dorsal and 1st lumbar vertebræ, from lumbar fascia, and three

lower ribs: beneath it was a large bursa and also a mass of firm white fat, weighing about 2 oz. The tendon of insertion was scarcely at all twisted on itself, as in man: insertion as usual.

The triceps accessorius (·05), triangular in shape, about one inch broad and long, and very thin, was inserted by a long fine tendon into the inner and posterior surface of the olecranon. Supplied by the musculo-spiral nerve.

Subscapularis (4·90), very thick. Pectoralis minor absent.

Pectoralis major (16·86) consisted of two layers, embracing between their insertions the triceps. The superficial layer arose from the median line of the thorax; closely connected with the opposite muscle. Insertion into a ridge on the outer surface of the humerus for about eight inches; also into the greater tuberosity, continuous below with the clavicular portion of the deltoid.

The deep, the smaller of the two, arose from the sternum, nearer its lateral margin, and was inserted into the lesser tuberosity, and a line leading downwards and forwards from it for about three inches.

Coraco-brachialis major, and subclavius, were absent.

The coraco-brachialis minor (·06) arose by a fine tendon from the upper border of the glenoid cavity. It soon became fleshy, and was inserted tendinous and fleshy, immediately below the facet for the subscapularis tendon, which it crossed over, on the lesser tuberosity. The above was symmetrical.

The deltoid, as usual, divisible into three portions—scapularis, acromialis, and clavicularis, though the division was more or less artificial in some places.

Scapularis, from spine of scapula to crest on humerus, = 1·60.

Acromialis (1·00), from acromion process, and where it should have arisen from the clavicle, was more or less fused with the clavicularis (1·85), which also arose from the acromion. The two latter became continuous with the triceps, about an inch from its insertion, there being no traceable connexion with the radius. A floating clavicle was developed in the substance of the clavicularis.

Supra- and infra-spinati as usual; tendon of insertion of former was fibro-cartilaginous. Respective weights 7·36 and 5·65.

Serratus magnus arose from upper ten ribs and formed one mass, not divisible into the three usual portions. Insertion was normal, but rather larger than usual, = 8·62.

The spino-glenoid ligament consisted of two layers with fat between, attached posteriorly to the under surface of the acromion, internally and posteriorly to base of acromion, and anteriorly to the edge of the glenoid cavity, forming an arch corresponding to the neck of the scapula, beneath which passed the supra-scapular nerve.

The biceps humeri (3·80) had only one head of origin from the scapula, immediately above the glenoid cavity, which pierced the capsular ligament, and united, at its insertion into the radius, with part of the tendon of the brachiæus.

The brachiæus (·62) arose from the greater part of the anterior

and inner surface of the humerus. The tendon of insertion was broad, and split into three parts.

The major was inserted into the anterior surface of the ulna, immediately underneath the origin of flexor profundus; the middle, small and round, into the anterior surface; and the smallest, united with the biceps tendon.

The triceps arose as usual by three heads, one scapular, and two humeral; between them the musculo-spiral nerve. Origin and insertion normal, the relation of the three heads was: longus, 10·50; externus, 4·26; internus, ·60.

Anconeus internus, or epitrochleo-anconeus (Gruber) (·05), was very distinct; it arose from the inner condyle, crossed over the ulnar nerve, and was inserted into the olecranon process. It was about an inch in length. The externus was absent.

The pronator radii teres (·35), normal. From the tendon of insertion, which was prolonged to within two inches of the end of the radius, a fine tendon was given off, which united with the palmar fascia.

The flexor carpi radialis (·20), thin, fleshy belly; inserted into second metacarpal, giving off slips to the styloid process of radius, and the trapezium, as it passed through the groove. The membrane completing the groove was very tough and strong.

The palmaris longus (·75), very large, took the ordinary course of the flexor sublimis, which was quite rudimentary, weighing only (·01). The latter arose from the front of the tendon of the flexor profundus, dividing into three tendons, and also giving off a slip to the flexor profundus. The three tendons went to the three middle digits of the manus, each of the three middle digits having thus two tendons, one from the palmaris longus, and one from the flexor sublimis. The fourth had only one, viz., from the palmaris longus. Opposite the metacarpo-phalangeal articulation the tendons united, sending off a process on each side. Insertion as usual.

Flexor carpi ulnaris (·70) arose by two heads, separated by the ulnar nerve.

Flexor digitorum profundus (2·06) and flexor longus pollicis (·15), which were intimately connected at their insertion, arose from radius, ulna, and interosseous membrane. The five tendons were united at the wrist, and passed to the five digits, being inserted into the last phalanges. The flexor sublimis arose from the front of the united tendons before they passed under the annular ligament, which was very strong.

The pronator quadratus (·16) extended up as far as the oblique ligament, which was placed lower than usual, about $1\frac{1}{2}$ inches below the tubercle of the radius.

The supinator radii longus and extensor carpi radialis brevior were both absent.

Extensor carpi radialis longior (·80), extensor carpi ulnaris (·28), and extensor ossis metacarpi pollicis (·12) had all normal origins and insertions.

Supinator radii brevis (·10), besides its usual radial insertion, had a

good many muscular fibres attached to the upper part of the interosseous membrane.

Extensor longus digitorum (·40) divided underneath annular ligament into four very thin weak tendons.

The extensor minimi digiti (auricularis) (·10) was inserted into the base of the second phalanx of the fifth digit. Extensor minimi digiti tertii (·05) arose from upper fifth of radius and external lateral ligament, ran alongside the auricularis, passing through a separate compartment of the annular ligament, and was inserted into the outer surface of the base of first phalanx of fifth digit.

Extensor carpi ulnaris (·28) arose from upper third of posterior border of ulna. Extensor indicis et pollicis (·05), made up of the extensor secundi internodii pollicis, and indicator, presented a rather remarkable arrangement. It arose fleshy by two heads—one from the external surface of ulna, one inch below olecranon, the other from the radius, above the superior radio-ulnar ligament; it then passed downwards, and, on the dorsum of the manus, crossed beneath the tendons of the extensor longus digitorum, and was inserted into the base of the claw of pollux. The above arrangement was symmetrical.

Adductor minimi digiti (·08).

There were four palmar interossei, weighing respectively ·06; ·05; ·02; ·01; the fourth corresponding to the interosseus of Henle in man. It arose from the deep palmar fascia, and was inserted into the dorsal aponeurosis of thumb.

The four dorsal interossei weighed respectively ·10; ·05; ·10; ·05.

The first palmar and first dorsal interossei were inserted in a peculiar manner, and the arrangement occurred on both sides. Attached to the posterior end of the base of each claw were two elastic bands—one on each side—which extended to a tubercle on the head of the phalanx. Into these bands the tendons of the first dorsal and palmar interossei were attached, about the middle, seemingly acting as retractors of the claw.

The palmar interossei being removed, a ligament was seen extending from the carpus to the fourth metacarpal bone. It was attached to the carpus by three slips: the middle one continuous with the external retinaculum of the pisiform; the internal one attached to the head of the fifth metacarpal; and the external, to the unciform and os magnum. Its other end was inserted into the fourth metacarpal, about its centre. Opposite the carpo-metacarpal articulation, and for a short distance down the fourth metacarpal, it was free, not attached to the bone; but I could discover no structure passing underneath it.

It was similar in every respect to a corresponding one in the pes.

The same arrangement occurred in the other manus.

The sartorius (5·21), broad and thin, covering the greater portion of the inside of the thigh, arose from the iliac spine and part of Poupart's ligament. Insertion into the lower surface of head of tibia.

Psoas parvus and magnus and the iliacus (10·00); the two former arose together normally, after keeping together for about five inches

they separated; the parvus, being inserted by a very broad tendon into the magnus, joined with the iliacus, to be inserted into the lesser trochanter of the femur.

Pectineus (·35), inserted into femur above and anterior to lesser trochanter. The adductores primus, secundus, α and β, and tertius (17·5), were inseparably connected.

The quadratus femoris (·55), large and strong, arose from the external surface of the tuber ischii, and was inserted below the posterior extremity of the oblique line on the great trochanter. Obduratores externus (1·60) and internus (·83) were well marked and normal, the gemelli being closely connected with the latter. The tendon of the internus exhibited a beautiful arrangement; there were five primary tendons, each of which split into two, and some of these again subdivided.

The agitator caudæ (2·40) arose broad and fleshy from the upper part of the ilium immediately behind the acetabulum, and from the two anterior caudal vertebræ, lying alongside of and slightly overlapping vastus externus. After about eight inches it ended in a long and fine tendon, which passed beneath the vastus externus tendon, to be inserted, together with the rectus, into the anterior margin of patella.

Gluteus maximus (1·5), very small, was easily separable from the tensor vaginæ femoris; quadrilateral in shape. It arose from the posterior border of the ilium, and was inserted tendinous into the outer part of femur, below the great trochanter.

The medius (5·72) and minimus (·50), quite separate, were normal. The quartus (·40), really an easily separable anterior portion of the minimus.

Quintus (·12) was also present, and symmetrical; it arose immediately in front of the acetabulum, and running downwards and backwards was inserted into the commencement of the oblique line on the great trochanter.

Pyriformis (·65), normal.

The tensor vaginæ femoris (3·90) (gluteus minimus of Cuvier) arose from the anterior fourth of the crest of the ilium, and was inserted by means of the ilio-tibial ligament, which was very strongly marked, into the outer and back part of the tibia.

The biceps femoris (10·03), the long head arising from the tuber ischii, was spread out in a thin layer over the greater portion of the outer surface of the thigh, partly overlapping the adductors. The femoral head arose from the junction of upper and middle thirds of posterior surface of femur; it soon joined with the long head, to be inserted into the head of the fibula.

Bicipiti accessorius, absent.

Semimembranosus (13·30) and semitendinosus (4·70) arose by a common tendon from tuber ischii. Insertion as usual.

The gracilis (5·00). Very broad thin layer spread over the posterior fold of the thigh, arising from greater part of symphysis pubis, and inserted by a very weak narrow tendon into upper part of tibia.

Rectus (4·60). The usual origin, by two heads, and insertion. Vastus externus (8·00) and vastus internus (4·67), normal.

The crureus (3·35), almost inseparably connected with the vastus externus; in some places there was no natural division.

The popliteus (·65): sesamoid bone developed in tendon of origin; the muscle, almost quadrilateral in form, occupied the upper third of tibia.

The gastrocnemius externus and soleus, (3·67) and internus (1·87) had both a sesamoid bone developed in their tendons of origin. The soleus was inseparably connected with the former.

Plantaris (·02) arose from the outer condyle. It was inserted along with the gastrocnemius.

Flexor longus digitorum and flexor hallucis longus (together = 2·07) were united in their whole extent. They sent tendons to the five digits of the pes.

The tendon only of the tibialis posticus was present, the muscular part was wanting; the tendon extended from immediately above the internal malleolus to the tuberosity of the scaphoid.

Flexor brevis digitorum: scarcely any distinguishable muscular fibres about (·05).

Accessorius flexori longo was absent.

The tibialis anticus (1·30) arose from the upper part of the outer surface of the tibia, external tuberosity and corresponding part of interosseous membrane. There were very weak intermuscular septa. Insertion as usual into the first metatarsal bone.

The extensor hallucis was inseparably connected with the extensor longus digitorum (1·50), at least as far as their muscular bellies were concerned, the tendons being quite distinct; insertion normal.

Peroneus quinti (·11), brevis (·02), and longus (·40), as usual.

Extensor brevis digitorum (·12) was as usual.

The muscles of the pes presented no features of interest. The dorsal and plantar interossei exhibited a curious relation to one another, the weights of the plantar being ·07; ·07; ·06—the dorsal being ·07; ·08; ·07; ·07. On clearing off the muscles, a rather remarkable ligament, which I believe has not hitherto been noticed, was brought into view. It was about four inches long, rounded, white, and shining, attached at one end to the middle and external cuneiform bones, covering nearly the whole of their under surfaces, and at the other to the posterior half of the fourth metatarsal bone, covering its lower surface and part of its sides opposite the tarso-metatarsal articulation; and for about the posterior quarter inch of the second metatarsal bone it was free, smooth and round. I could discover no trace of a nerve or artery passing between it and the bone; it was symmetrical. An analogous one was present in the manus.

Muscles of the Fore Limb.

		Avoirdupois Ounces.
1.	Trapezius, Clavicularis,	1·20
	Scapularis superior, and trachelo-acromialis,	2·65
	Scapularis inferior,	1·40
2.	Sterno-mastoid,	—
3.	Cleido-mastoid,	0·70
4.	Rhomboideus, Major,	0·90
	Minor and occipital,	2·75
5.	Teres major,	3·35
6.	Teres minor,	0·31
7.	Latissimus dorsi,	12·36
8.	Subscapularis,	4·90
9.	Pectoralis major,	16·86
10.	Coraco-brachialis minor,	0·60
11.	Deltoideus scapularis,	1·60
12.	Deltoideus acromialis,	1·00
13.	Deltoideus clavicularis,	1·85
14.	Supraspinatus,	7·36
15.	Infraspinatus,	5·65
16.	Serratus magnus,	8·62
17.	Biceps humeri (scapularis),	3·80
18.	Brachiæus,	0·62
19.	Triceps longus,	10·50
20.	Triceps internus,	0·60
21.	Triceps externus,	4·26
22.	Triceps accessorius,	0·05
23.	Anconeus internus,	0·05
24.	Pronator radii teres,	0·35
25.	Flexor carpi radialis,	0·20
26.	Palmaris longus,	0·75
27.	Flexor carpi ulnaris,	0·70
28.	Flexor digitorum sublimis,	0·01
29.	Flexor digitorum profundus,	2·06
30.	Flexor pollicis longus,	0·15
31.	Pronator quadratus,	0·16
32.	Extensor carpi radialis longior,	0·80
33.	Supinator radii brevis,	0·10
34.	Extensor digitorum longus,	0·40
35.	Auricularis,	0·10
36.	Auricularis tertii,	0·05
37.	Extensor carpi ulnaris,	0·28
38.	Extensor ossis metacarpi pollicis,	0·12
39.	Extensor pollicis et indicis,	0·05
40.	Adductor minimi digiti,	0·08

1, 2, 3, 4, Palmar interossei, 0·06, 0·05, 0·02, 0·01.
1, 2, 3, 4, Dorsal interossei, 0·10, 0·05, 0·10, 0·05.

Muscles of the Hind Limb.

	Avoirdupois Ounces.
1. Sartorius,	5·21
2. Psoas parvus,	2·35
3. Psoas magnus, 4. Iliacus,	10·00
5. Pectineus,	0·35
6. Adductor primus, 7. Adductor secundus, *α*, 8. Adductor secundus, *β*, 9. Adductor tertius,	17·50
10. Quadratus femoris,	0·55
11. Obdurator externus,	1·60
12. Obdurator internus,	0·83
13. Agitator caudæ,	2·40
14. Pyriformis,	0·65
15. Gluteus maximus,	1·50
16. Gluteus medius,	5·72
17. Gluteus minimus,	0·50
18. Gluteus quartus,	0·40
19. Gluteus quintus,	0·12
20. Tensor vaginæ femoris,	3·90
21. Biceps femoris,	10·03
22. Semimembranosus,	13·30
23. Semitendinosus,	4·70
24. Gracilis,	5·00
25. Rectus femoris,	4·60
26. Vastus externus,	8·00
27. Vastus internus,	4·67
28. Crureus,	3·35
29. Popliteus,	0·65
30. Gastrocnemius externus, 31. Soleus,	3·67
32. Gastrocnemius internus,	1·87
33. Plantaris,	0·02
34. Flexor longus digitorum, 35. Flexor longus hallucis,	2·07
36. Flexor digitorum brevis,	0·05
37. Tibialis anticus,	1·30
38. Extensor hallucis, 39. Extensor digitorum longus,	1·50
40. Peroneus quinti,	0·11
41. Peroneus brevis,	0·02
42. Peroneus longus,	0·40
43. Extensor brevis digitorum,	0·12

1, 2, 3, Plantar interossei, 0·07, 0·07, 0·06.
1, 2, 3, 4, Dorsal interossei, 0·07, 0·08, 0·07, 0·07.

III.—On a Series of Bases derived from Pyrrol, and some Compounds allied to them and to Mucic Acid. By Chichester A. Bell, M.B.

[Read, January 22, 1877.]

Since the discovery of pyrrol in coal-tar by Runge, and its subsequent isolation by Anderson from the destructive-distillation products of bones, few attempts seem to have been made to explain its chemical constitution, or to ascertain its relations with other substances. This is remarkable, because, for many reasons, its study is likely to prove of interest; and chiefly, indeed, because it is the simplest representative of that large class of nitrogenous bodies whose chemical history was, until quite recently, enveloped in complete darkness, and is even yet by no means satisfactorily cleared up; which form, as it were, the connecting link between the true ammonia bases on the one hand, and the hydrocyanic ethers or nitriles on the other, sharing as they do the basic characters of the first, and the active toxic and physiological properties of the second. I allude to such bodies as conine, nicotine, the pyridine and chinoline series, etc. As an unstable body, also, pyrrol claims our attention, for it may be laid down as a rule in chemical research—at least so far as modern chemical doctrines are concerned—that the more prone to change any substance is, the more fruitful in theoretic results its examination is likely to prove.

But while in itself pyrrol offers many points of interest to the scientific chemist, its importance has been much enhanced by the discovery, due to Malaguti and Schwanert,[1] that it and a closely-allied substance, the so-called *carbo-pyrrol-amide*, are the chief products obtained when the ammonia salt of mucic acid, an acid easily obtained by the oxidation of lactose (sugar of milk) or galactose, is exposed to a temperature above 220° C.; an importance which I venture to think is much heightened by the observation made by my friend Dr. Edwin Lapper and myself, that it is with still greater ease formed from the ammonia salt of the isomeric saccharic acid, the principal oxidation product of ordinary cane sugar, etc. The smoothness of the reaction by which it is in both cases produced leads to the suspicion that it is, in the true sense of the word, a decomposition-product of these salts, and hence that it is intimately connected with them by molecular relations. For these reasons I have undertaken the study of its metamorphoses, etc., and as the first-fruits of my researches I beg to lay before the Academy the results at which I have so far arrived.

The reaction in virtue of which pyrrol is obtained from ammonium mucate is very simple, and may be thus represented:—

Ammonium mucate. Pyrrol.

$$C_6H_8(NH_4)_2O_8 = C_4H_5N + NH_3 + 2CO_2 + 4H_2O.$$

[1] "Annalen der Chemie und der Pharmacie," cxvi., 278.

This is the final result; but at the same time there is formed, in considerable quantity, the so-called *carbo-pyrrol-amide*, of which pyrrol is usually regarded as a direct decomposition-product:—

$$\underset{\text{Ammonium mucate.}}{C_6H_8(NH_4)_2O_8} = \underset{\text{Carbo-pyrrol-amide.}}{C_5H_6N_2O} + CO_2 + 5H_2O.$$

We may then assume that, by the action of a molecule of nascent water on carbo-pyrrol-amide, pyrrol is formed.

$$C_5H_6N_2O + H_2O = C_4H_5N + NH_3 + CO_2.$$

This view is borne out by the fact that if the amide be boiled with barium hydrate, ammonia is evolved, and the barium salt of the monobasic *carbo-pyrrolic acid* is obtained in solution (Schwanert):

$$C_5H_6N_2O + H_2O = \underset{\text{Carbo-pyrrolic acid.}}{C_4H_4N(COOH)} + NH_3;$$

which acid, at a temperature slightly above its fusing-point, splits up into pyrrol and carbonic anhydride,

$$C_4H_4N(COOH) = C_4H_5N + CO_2.$$

This decomposition may be compared with those by which phenol is produced on heating salicylic and paraoxybenzoic acids; citraconic and itaconic acids on heating aconitic acid, etc. Carbo-pyrrolic acid may then be regarded as a carboxyl derivative of pyrrol: that is, as pyrrol in which the group COOH takes the place of an atom of hydrogen.

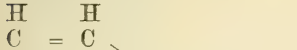
Pyrrol is a colourless pleasantly-smelling liquid, boiling at 133° C. It dissolves, although slowly, in dilute mineral acids; but all attempts to obtain simple or double salts of it have failed. The free base, however, gives with an alcoholic solution of mercuric chloride a semi-crystalline precipitate, $C_4H_5N, 2HgCl_2$, which may be compared with the precipitates produced by ammonia under the same circumstances.

Pyrrol is an extremely unstable compound. Exposed to air, it soon becomes brown, and its solutions in acids decompose, slowly in the cold, rapidly on boiling, into ammonia and the so-called *pyrrol-red*, $C_{12}H_{14}N_2O$ (Schwanert), $C_{12}H_{10}O_2$ (Limpricht). Other of its reactions will be alluded to farther on.

Respecting its chemical constitution, Kekulé ("Lehrbuch der Chemie," vol. ii., p. 408) views it as an amine, one atom of hydrogen in ammonia being displaced by the radicle C_4H_3, thus, $\left.\begin{matrix} C_4H_3 \\ H \\ H \end{matrix}\right\}$ N. Wichelhaus,[2] however, has shown that this view is untenable, since it reacts neither with chloroform, with bisulphide of carbon, nor with ethyl iodide, with which reagents all primary amines combine energetically.

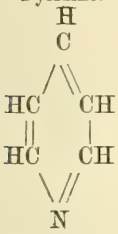
[2] "Berichte der deutschen Chemischen Gesellschaft," ii.

Accordingly, Baeyer and Emmerling[3] have proposed for it the constitutional formula

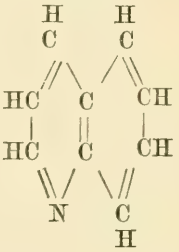


Similar formulæ have been ascribed to pyridine and chinoline, in which the affinities of the nitrogen are supposed to be saturated by two carbon atoms, connected with each other through the intervention of other carbon atoms.

Pyridine.



Chinoline.



The experiments which I have to describe, while they confirm the view that pyrrol is not a primary amine, lend considerable support to the ideas of Baeyer and Emmerling regarding its constitution.

Experience having shown that an unstable body frequently acquires stability by the substitution of acid or alcoholic radicles for its displaceable hydrogen, my first efforts have been directed towards obtaining derivatives of pyrrol. Two experiments have already been made in this direction: one by Lubawin,[4] who made the interesting observation that potassium is capable of removing one atom of hydrogen in pyrrol, and that the potassium-pyrrol, C_4H_4KN so formed, when treated with ethyl iodide, furnishes potassium iodide, and a liquid the analysis of which corresponds approximately to the formula of an ethyl-pyrrol $C_4H_4(C_2H_5)N$. This he describes as a liquid possessing a turpentine-like odour, which boils between 155° and 175° C. (!), and rapidly turns red on contact with air. He considers it probable that in these bodies the potassium, and consequently the ethyl, are substituted for an atom of hydrogen in the hydrocarbon nucleus which may be assumed to exist in pyrrol regarded as an imide base $(C_4H_4)''NH$.

Köttnitz,[5] on the other hand, by the dry distillation of the mucate

[3] "Chemisches Centralblatt," 1870, p. 437.
[4] "Zeitschrift fur Chemie," [2] v. 399.
[5] "Journal für Prakt. Chemie," [2] vi. 136-156.

of aniline obtained, besides the phenyl derivatives of mucamide, two bodies of neutral character, one of which he regards as phenyl-pyrrol $C_4H_4(C_6H_5)N$. The second, which is only formed in small quantity, corresponds to the formula $C_{16}H_{14}N_2$. For this he proposes the constitutional formula $C_4H_4 \begin{matrix} NC_6H_5 \\ NC_6H_5 \end{matrix}$. From toluidine mucate he obtained only the homologue of this latter substance, $C_{18}H_{18}N_2$, but no tolyl-pyrrol. In phenyl-pyrrol it is highly probable, from the nature of the reaction, that the group C_6H_5 remains in connexion with the nitrogen, and Köttnitz argues, by analogy, that the same position must be assigned to the residue ethyl in Lubawin's ethyl-pyrrol. That this cannot be the case will be rendered evident by the results of my experiments.

The plan of procedure which I have adopted is essentially that of Köttnitz. I have, however, experimented in addition with secondary and tertiary monamines, in view of the possibility of obtaining di- and tri-derivatives of pyrrol. In this respect my expectations have not been fulfilled, and thus the view of Wichelhaus and of Baeyer and Emmerling, viz., that pyrrol does not contain the residue NH_2, has received strong confirmation. I have, however, succeeded in producing a series of bases derived from pyrrol, besides other allied bodies which have no analogues amongst those described by Köttnitz. These I proceed to describe.

Distillation of Ethylammonium Mucate.

This salt is easily formed by bringing together solutions of ethylamine and mucic acid in equivalent proportions. The acid is rapidly dissolved with development of heat, and on evaporation and *slow cooling* the mucate is obtained in large, transparent, slightly oblique, rhombic prisms, which are freely soluble in water, less so in alcohol. These appear to correspond to the formula $C_6H_{10}O_8 \cdot 2NH_2(C_2H_5) + 8\,H_2O$. They effloresce on exposure to air, quickly losing the whole of their water of crystallization. If dried in the water bath, the salt experiences slight dissociation, some ethylia being given off. The same occurs when a concentrated solution of it is boiled. The crystals are, therefore, best dried *in vacuo* over sulphuric acid. When crystallized from water at a high temperature, or from strong alcohol, the salt is deposited in the anhydrous form. A determination of the ethylia evolved on heating the dried salt with caustic potash proved it to have the composition $C_6H_{10}O_8$, $2NH_2C_2H_5$.

Exposed to heat, mucate of ethylia first melts, and then decomposes with intumescence. To obtain its distillation-products direct heating over the lamp is not advisable. The operation is advantageously conducted in a long-bodied retort, or, better still, in a tall and thin-sided bottle, secured in a paraffin bath furnished with a

thermometer. The retort or bottle containing the *thoroughly-dried* mucate is connected, the latter by means of a wide tube, with an efficient condenser, and the temperature of the bath gradually raised. At about 136° C. the salt shows signs of decomposition, while the distillation proceeds rapidly, but not tumultuously, when the bath is heated to 190° C. If an ordinary retort be employed, it is almost impossible to prevent the intumescent mass from frothing over. Water at first comes over, with ethylamine in abundance, while carbonic anhydride is the only gaseous product. After a time, minute oily drops, which gradually increase in bulk and number, appear in the condenser, and when the operation is ended, as indicated by the cessation of the evolution of gas, the liquid in the receiver is found to consist of two layers—a lower watery one holding in solution carbonate of ethylium and free ethylia, and an upper oily stratum possessing an odour closely resembling that of pyrrol. To purify the latter, it is shaken up twice or thrice with its own bulk of water, and then with very dilute sulphuric acid, in order to remove the last traces of ethylia; again washed with potash solution and water, and finally dried over calcium chloride. Submitted to fractional distillation, if the material used in its preparation were perfectly pure, it commences to boil at a few degrees below 131° C., the thermometer rapidly rising to that temperature, at which it remains until about half the liquid in the retort has passed over. This is collected separately. On continuing the heat the thermometer again quickly rises, until at 269°–270° it becomes stationary. The distillate at this temperature solidifies in the condenser and tube of the retort. The products boiling at these two temperatures constitute almost the entire mass of oily distillate.

When the bottle, or retort, in which the distillation has been conducted, is allowed to cool, it is found to contain a mass of crystals, saturated with an oily liquid identical with the high-boiling liquid previously obtained. The two substances may be easily separated by means of cold alcohol, in which the crystalline residue is very slightly soluble, while the oily liquid is miscible with it in all proportions. The solid is then repeatedly crystallized from boiling rectified spirit, when it is obtained in delicate needles, melting at 229°–230° C. (uncorrected). The cold alcoholic residue is evaporated on the water bath to remove the spirit, and may then be at once distilled, when it furnishes a large amount of the product boiling at 269°–270° C. It is better, however, to distil it by means of a current of steam from a retort placed in a paraffin bath heated to about 220°. The distillate then consists of a heavy oil, the high-boiling product in question, surmounted by a layer of water; from the latter, by shaking with ether, an additional quantity may be recovered. The collected products may be again distilled, and the portions coming over at about 270° C. induced to solidify by contact with one of the crystals first obtained.

The three products resulting from an operation conducted as above were separately examined.

The liquid of low boiling point, after a few rectifications, distilled at 131°, and on analysis yielded the following results:—

	Experiment.			Calculated for
	I.	II.	III.	$C_4H_4(C_2H_5)N$.
C	= 75·92	—	—	75·79
H	= 9·71	—	—	9·47
N	= —	14·58	14·69	14·83

That it was an ethyl-derivative of pyrrol is thus proved by its analysis, and the circumstances under which it was produced.

Ethyl-pyrrol is a colourless liquid of sp. gr. ·9042 at 10° C., ·8936 at 15° C. It possesses an odour closely resembling, but still distinguishable from that of pyrrol. Like that body, it is very sparingly soluble in cold water or in dilute acids, easily in concentrated hydrochloric, nitric, or acetic acids. Sulphuric acid also dissolves it, giving a dark-coloured solution which strikes a deep black with potassium bichromate. Its vapour, like that of pyrrol, colours fir-wood moistened with hydrochloric acid an intense crimson. With alcoholic mercuric chloride it gives a white precipitate. Its alcoholic solution gives a dark colour with platinum tetrachloride, but no precipitate, even on standing for twenty-four hours (difference from pyrrol).

By their behaviour with concentrated acids the two bases are strikingly distinguished. When pyrrol is boiled with strong hydrochloric acid, it is converted in a few seconds into a jelly-like mass of pyrrol-red; whereas the ethyl-derivative may be boiled for some time with the concentrated acid, and afterwards, by dilution, precipitated unaltered. Both pyrrol and ethyl-pyrrol are oxydized with explosive violence on gentle warming with strong nitric acid; and in the cold the former is quickly converted into pyrrol-red. But if ethyl-pyrrol be dissolved in a minimum of cold nitric acid, the mixture on standing for some time deposits a thick, oily liquid, which may be redissolved by a slight addition of acid, only to reappear soon. When freed from nitric acid and pyrrol, by washing with water, this liquid does not give the fir-wood reaction, either alone or when heated with potash. It is in all probability a nitro-derivative. I propose to examine it further.

If bromine be added to ethyl-pyrrol or to its solution in ether, chloroform, acetic acid, etc., the mixture becomes black and tarry, giving off hydrobromic acid. But if a freshly-prepared and cooled solution of bromine in alcohol be cautiously added to an alcoholic solution of ethyl-pyrrol, at a certain point, the latter deposits crystals of a compound, melting about 90° C., quite insoluble in water, and but sparingly taken up by strong spirit. It is probably an addition product; but I have not yet obtained it in sufficient quantity to examine it completely. Under no circumstances have I been able to obtain such a body from pyrrol.

The liquid boiling at 269°–270°, when pure, solidifies slowly to a mass of long and thick prisms, which are more rapidly but not so

beautifully formed when a ready-formed crystal is introduced into it. But the presence of even very small quantities of foreign bodies suffices to retard the crystallization to an extraordinary degree, or even to hinder it altogether. In boiling water this substance is tolerably soluble, and separates on cooling in the form of oily drops, which after some days solidify. It melts at 43°–44° C. when dry; when moist, at a much lower temperature: wherefore it is necessary to avoid breathing on it or touching it with the fingers.

Its analysis gave the following results:—

Experiment.	Calculated for diethyl-carbo-pyrrol-amide. $C_5H_4(C_2H_5)_2N_2O$.
C = 64·56	65·06
H = Lost	8·43
N = 16·68	16·86

It is without doubt a diethyl-derivative of Schwanert's carbo-pyrrol-amide. Its formula may therefore be written:—$C_4H_3(NC_2H_5)(CONHC_2H_5)$. It is a remarkably stable body. When pure it is quite permanent in air, and may be distilled unaltered. Its behaviour towards alkalies is peculiar. Prolonged boiling with aqueous potash or barium hydrate fails to affect it in the slightest degree, and even after boiling for hours with a large excess of alcoholic potash, nearly the whole of it may be recovered unaltered. Strong acids dissolve it easily, and yield it unchanged on dilution. The hydrochloric and acetic acid solutions may even be boiled without decomposition ensuing.

The crystalline substance, sparingly soluble in cold alcohol, which is left in the retort when ethylammonium mucate is distilled, is dissolved by concentrated acids, precipitated on dilution, and, in fact, presents all the characters of an amide. In water it is completely insoluble. Analysis conducted to the formula $C_{12}H_{19}N_3O_2$:—

Experiment.		Calculated for $C_{12}H_{19}N_3O_2$.
I.	II.	
C = 60·8	60·51	60·76
H = 8·28	8·51	8·14
N = 17·88	17·55	17·72

This peculiar body strongly resists decomposition. By careful heating it may be sublimed unaltered, and may be boiled with either aqueous or alcoholic potash, without suffering any change. Heated in a test-tube with soda-lime, it is partially decomposed, giving off ethylamine and a vapour which exhibits the fir-wood reaction, and is therefore, presumably, ethyl-pyrrol.

The changes occurring then during the distillation of ethylammonium mucate are the following; it will be convenient to

present mucic acid as the dicarboxyl derivative of a radicle $C_4H_{10}O_4$:—

$$(1)\quad C_4H_8O_4 2COON(C_2H_5)H_3 = \underset{\text{Ethyl-pyrrol.}}{C_4H_4(C_2H_5)N} + 2CO_2 + NH_2C_2H_5 + 4H_2O.$$

$$(2)\quad C_4H_8O_4 2COON(C_2H_5)H_3 = \underset{\text{Diethyl-carbo-pyrrol-amide.}}{C_5H_4(C_2H_5)_2N_2O} + CO_2 + 5H_2O.$$

In order to explain the formation of the third product, $C_{12}H_{19}N_3O_2$, we must assume that a molecule of ethylia, liberated according to equation (1), enters into reaction with a molecule of unaltered mucate, forming water and the new body :—

$$(3)\quad C_4H_8O_4 2COON(C_2H_5)H_3 + N(C_2H_5)H_2 = C_{12}H_{19}N_3O_2 + 6H_2O.$$

The quantity of this latter produced appears to increase with the purity and dryness of the salt operated on, and the slowness with which the distillation is conducted. The presence of even a small quantity of di- or tri-ethylamine prevents its appearance altogether. This is readily explained, since I have found that on heating a mixture of ethylium and diethylium mucate, the base expelled in the free state consists chiefly of diethylia, which evidently could not enter into reaction (3).

In fact, the yield of ethyl-pyrrol under these circumstances is considerably greater than when the pure primary amine is employed.

In the case of a double salt of primary and secondary ethyl-ammonium, for example, the reaction appears to take place principally, though not quantitatively, according to the following equation :—

$$C_4H_8O_4 \begin{cases} COON(C_2H_5)H_3 \\ COON(C_2H_5)_2H_2 \end{cases} = C_4H_4(C_2H_5)N + 2CO_2 + N(C_2H_5)_2H + 4H_2O.$$

For the preparation of ethyl-pyrrol, then, the mixture of bases furnished by digesting ethyl-iodide with ammonia, after removal of the ammonia, may be used with advantage.

The relations of the body $C_{12}H_{19}N_3O_2$ will be discussed further on.

Distillation of Methylammonium Mucate.

This salt is also easily prepared by shaking up the requisite weight of mucic acid with a somewhat dilute methylamine solution. The mixture becomes warm, and if sufficient water is present the acid is completely dissolved. On evaporation the mucate is obtained in anhydrous crystals. It is much less soluble than the corresponding ethylia salt, and may, with little loss, be crystallized from boiling water. Even boiling alcohol scarcely dissolves it.

Exposed to a temperature of 180°–190° C. in the apparatus previously described, it is decomposed with intumescence and evolution of carbonic anhydride, and the production of a mixed aqueous and oily

distillate. The oily layer consists of *methyl-pyrrol*, holding in solution a small quantity of *dimethyl-carbo-pyrrol-amide*. The two are easily separated from the thoroughly washed and dried mixture by fractional distillation. The greater part of the amide, however, remains in the decomposing-retort, and may be easily extracted by distillation at about 200° C. in a current of steam, when it comes over as a heavy oil, which soon solidifies. From the water which accompanies it, large and beautifully-formed crystals are deposited after it has remained undisturbed for a few days.

If, after the second distillation is terminated, the black residue in the retort be treated with warm alcohol, it will be found to dissolve almost completely; the solution, on cooling, deposits small hard crystals, which may be the methyl analogue of the body $C_{12}H_{19}N_3O_2$. All my efforts to obtain these crystals in a form suitable for analysis have as yet failed, and the smallness of their quantity has prevented me ascertaining their physical and chemical characters with exactness.

Methyl-pyrrol is a colourless, mobile, and volatile liquid, of specific gravity ·9203 at 10° C., and boiling point 112°–113° C.; the latter is 20°–21° lower than that of pyrrol. On exposure to air it slowly becomes brown. Its odour recals at once those of pyrrol and of ethyl-pyrrol, but is distinguishable from both. With nitric acid, bromine, and other reagents, it behaves exactly like the latter. Its composition is clearly proved by the following analysis:—

Experiment.	Calculated for $C_4H_4(CH_3)N$.
C = 73·9	74·07
H = 8·91	8·64
N = 17·26	17·28.

Dimethyl-carbo-pyrrol-amide is a crystalline body, melting at 89°–90° C., and boiling at about 260° C. In all its chemical characters it resembles the corresponding ethyl compound, exhibiting the same indifference towards strong acids and alkalies. It is, however, much more soluble in water, hot or cold. When caused to crystallize rapidly from its cold supersaturated solution it appears in thin glistening scales; but when it separates spontaneously it forms hard transparent massive prisms. Its analysis yielded the following results:—

Experiment.	Calculated for $C_5H_4(CH_3)_2N_2O$.
C = 60·62	60·87
H = 7·58	7·24
N = 20·24	20·29.

Its fusing point is intermediate between that of carbo-pyrrol-amide (173° C.) and that of diethyl-carbo-pyrrol-amide (44° C.).

Distillation of Amylammonium Mucate.

Like its congeners, this salt is easily prepared by bringing together an aqueous solution of amylamine[6] and mucic acid. On evaporation, it is obtained as a confusedly crystalline mass, exceedingly soluble in water and alcohol, and difficult to obtain in well-defined crystals. I have therefore not examined it particularly, but have submitted the salt, after thorough drying on the water bath, to distillation. This was conducted as already described, but towards the close of the operation the bath was allowed to attain a temperature of 200° C., although this was by no means necessary for the decomposition, which took place between 160° and 180°. The distillate was chiefly water, holding in solution amylammonium carbonate, on the surface of which floated a small quantity of a very agreeably-smelling oil, which was separated, purified, and dried, as described for ethyl-pyrrol. When distilled, it commenced to boil at 179° C.: the thermometer rose quickly to 188° C., when nothing more came over. On cooling, the residue solidified. The liquid which passed over between 179°–188° C., after standing for some days, deposited a few needles, and on redistillation again gave a residue which solidified. To free it from this crystalline body the rectification had to be many times repeated. Finally I succeeded in isolating a colourless liquid, of a fragrant, but somewhat oppressive odour. Sp. gr. (at 16° C.), ·8786. It boiled between 180° C. and 184°. Analysis yielded results agreeing with the formula $C_4H_4(C_5H_{11})N$.

	Experiment.	Calculated for $C_4H_4(C_5H_{11})N$.
C	= 78·83	78·83
H	= 11·28	10·95.

The yield from 25 grams. of amylamine (the quantity which I employed) only equalled a few cubic centimeters. I did not, therefore, make a nitrogen determination, the nature of the liquid being already sufficiently established. It could be no other than amyl-pyrrol. In its reactions, so far as I have examined them, it resembles the methyl and ethyl derivatives. It is, however, nearly insoluble in water, and retains its freedom from colour for a long time.

The residue from the distillation of the mucate consisted almost entirely of diamyl-carbo-pyrrol-amide, which was indeed by far the most abundant product. I did not examine it for the amyl analogue

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[6] Amylamine may be most advantageously prepared by Wurtz's process from cyanate of silver and amyl iodide, since Grimm has taught us an easy and rapid method of procuring the latter. For the preparation of cyanates, see a process which I have given ("Chemical News," vol. xxxii. p. 99). The formation of amyl cyanate and cyanurate (almost a quantitative reaction) takes place in a few hours in sealed tubes at 160° C. I have also found that amyl bromide, contrary to what is usually stated, when digested with alcoholic ammonia for a couple of days at 100° C., furnishes a considerable quantity of the primary amine.

of $C_{12}H_{19}N_3O_2$. Since, however, I found in the watery distillate an amount of amylia corresponding to the yield of amyl-pyrrol, I am perfectly satisfied that it was not formed. The amide is best extracted by distillation over the naked flame, the heat being removed as soon as the drops which condense in the neck of the retort become highly coloured. The distillate quickly solidifies, and may be purified by crystallization from boiling 60 per cent. alcohol, time being always allowed for the oily drops which first separate to assume the solid form. Diamyl-carbo-pyrrol-amide is then obtained in long and delicate needles, which melt at 77° C. It is still less easily attacked by alkalies than its methyl and ethyl analogues. Prolonged boiling with baryta water or with aqueous or alcoholic potash fails to alter it in the slightest degree; and even when distilled from soda lime, its very partial decomposition is only betrayed by the powerful odour of the amyl-pyrrol evolved. The greater part of it sublimes unchanged. Nevertheless, the following analyses leave no doubt as to its composition:—

	Experiment.			Calculated for
	I.	II.	III.	$C_5H_4(C_5H_{11})_2N_2O_2$.
C =	71·89	72·19	–	72·0
H =	10·66	–	–	10·4
N =	–	–	11·02	11·2.

The following reactions occur, then, during the dry distillation of amylammonium mucate.

Amyl-pyrrol.

(1) $C_4H_8O_4 2COON(C_5H_{11})H_3 = C_4H_4(C_5H_{11})N + 2CO_2 + (C_5H_{11})H_2N + 4H_2O.$

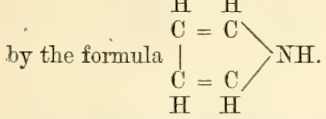
Diamyl-carbo-pyrrol-amide.

(2) $C_4H_8O_4 2COON(C_5H_{11})H_3 = C_5H_4(C_5H_{11})_2N_2O + CO_2 + 5H_2O.$

Experiments which I have made with the mucate of phenylene-diamine (meta), owing probably to the easy alterability of the products, have as yet led to no definite results. In a future communication I hope to describe experiments with the salts of allylamine, naphthylamine, and ethylene- and phenylene-diamines.

Having established the fact that by distillation of the mucates of primary amines we obtain mono-derivatives of pyrrol, it seemed next of interest to ascertain whether the secondary amines would, under similar circumstances, give rise to twice substituted derivatives. If pyrrol were an amine of the form $(C_4H_3)H_2N$, as Schiff and Kekulé originally surmised, we might expect to obtain such derivatives; but

they are theoretically impossible if its constitution is truly represented



by the formula

As will be seen, I have not obtained them; and this fact, I think, tends to confirm the theory of Baeyer. I have experimented with the mucates of diethyl and diamyl-amine.

Distillation of Diethylammonium Mucate.

This salt is obtained by dissolving mucic acid in solution of diethylamine, evaporating and crystallizing. It contains water, and is extremely soluble both in that liquid and in alcohol. When heated in the paraffin bath it decomposed with intumescence and evolution of carbonic anhydride, like the primary salt, but at a somewhat lower temperature. The distillate, as before, was a watery solution of diethylammonium carbonate, on the surface of which floated a small quantity of an oily liquid, possessing the odour, boiling point, and other characters of ethyl-pyrrol. This was evidently due to the presence of some primary amine in the diethylamine used.[7]

The retort residue was a black, carbonaceous mass, burning with flame, from which neither by solvents nor by further heating could anything suitable for analysis be extracted.

Distillation of Diamylammonium Mucate.

Easily formed by the direct union of diamylamine[8] and mucic acid. The resulting compound is freely soluble in water and alcohol. The distillation, which was slowly conducted over the naked flame, in every respect resembled that of the preceding salt. Owing

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[7] The diethylamine was prepared from diethyloxamic ether, boiling within a few degrees of 264° C. As obtained in the separation of the ammonia bases by oxalic ether, it is impossible (at least on the small scale) to separate it from simultaneously-formed monoethyloxamic ether (Wallach). Hence the presence of ethylia in the diethylia extracted from it by caustic potash. Baeyer ("Berichte," vii. 963) has now shown that by the action of caustic soda on nitroso-diethyl-aniline and nitroso-dimethyl-aniline, dimethylamine and diethylamine may be obtained in a state of absolute purity. But as this method, the only really satisfactory one, is somewhat costly, I propose to separate the primary and secondary bases by the distillation of their mucates. If the quantity of primary base be small, the secondary base will alone be liberated in the free state. I am not, however, prepared with analytical proofs.

[8] Diamylamine is usually stated, on the authority of its discoverer, Hofmann, to boil at 170° C. I have found, however, that it (that is, the variety prepared from ordinary amylic alcohol) boils at 185°-187°. That which I employed in these experiments boiled within a few degrees of this temperature, and yet evidently contained much amylamine (B.P. 95° C.). I am convinced that the complete separation of the primary, secondary, and tertiary amylamines by fractional distillation is as little feasible as that of the ethyl bases by the same process.

to the very sparing solubility of diamylamine in water, the greater part of it formed a layer on the top of the distillate. This layer included a not inconsiderable quantity of amyl-pyrrol and of diamyl-carbo-pyrrol-amide, no doubt due to the presence of amylamine in the salt operated upon. They were easily detected and isolated, when the diamylamine was converted into hydrochlorate. The retort-residue presented the appearance previously described.

Distillation of Triethylammonium Mucate.

Although in view of the results obtained with the secondary amines little could be expected from the experiment, I have nevertheless, for the sake of completeness, executed it.

Triethylamine combines with mucic acid to form an extremely soluble compound, which crystallizes in long prisms. On heating a strong solution of the salt it undergoes dissociation (decomposition?), triethylamine being given off, while the liquid becomes strongly acid. When distilled in the paraffin bath this salt also decomposed at about 170°, the sole products being a carbonaceous residue, as before, and a clear solution of triethylia carbonate, on the surface of which floated some free triethylia. The residue, which resembled in appearance and properties those previously obtained, was not minutely examined.

It is now clear that the primary amine salts of mucic acid are alone capable of furnishing by distillation derivatives of pyrrol. The fact that these derivatives are generated at a lower temperature, and with fewer secondary products, than pyrrol itself from ammonium mucate, strengthens us, I think, in the conviction that the group C_4H_4, existing in them, must in some way form the base on which the molecules of mucic acid, galactose, and possibly of many other sugars, are constructed.

It is quite evident that the methyl, ethyl, and amyl groups in these derivatives must stand in direct connexion with the nitrogen. In fact the bases of this series cannot be regarded as true homologues of pyrrol, since the fatty radicles are simply introduced into the lateral chain = NH, and not into the hydrocarbon nucleus. In this respect it is interesting to contrast their boiling points and other physical properties. It will be observed that the introduction of the methyl group into the pyrrol molecule at once lowers the boiling point about 21°, instead of raising it; but that, starting from methyl-pyrrol, the boiling points exhibit approximately the common difference of 19° for each addition of CH_2.

	Boiling Points.	Difference from preceding Term.
Pyrrol, . . .	133°	—
Methyl-pyrrol,	112–113°	− 20° to − 21°
Ethyl-pyrrol, .	131	+ 18 to + 19
Amyl-pyrrol, . .	180–184	+ 17 × 3 9. p.

The above boiling points are uncorrected. In the case of amyl-pyrrol, since the quantity of liquid was small, and the thermometer by no means all that could be desired, the correction to be applied would in all probability amount to five or six degrees, which would bring its boiling point into still closer conformity with Kopp's law.

On the other hand, the ethyl-pyrrol obtained by the action of ethyl iodide on potassium-pyrrol is stated by Lubawin, its discoverer, to boil between 155° and 175° C. From the description given of it, the compound was manifestly in an impure state; but if obtained free from foreign matter it would, no doubt, be found to have the boiling point $133 + 19 \times 2 = 171°$ C. It is, in short, a true homologue of pyrrol. The isomerism of these two ethyl-derivatives may be explained by the following constitutional schemes:

Pyrrol.	Ethyl-pyrrol (Lubawin).	Ethyl-pyrrol.
$(C_4H_4) = N$	$H(C_4H_3\,(C_2H_5)\,) = NH$	$(C_4H_4) = N\,(C_2H_5)$.

We may, I think, reject as disproved the surmise of Köttnitz, that in Lubawin's ethyl-pyrrol the ethyl is united to the nitrogen.

If these formulæ are correct, it should be possible to substitute in the compound $C_4H_4N\,(C_2H_5)$, by Lubawin's process, an ethyl group for one of the nuclear atoms of hydrogen, and so to arrive at the base $C_4H_3\,(C_2H_5)\,NC_2H_5$. I have, in fact, observed that potassium acts on ethyl-pyrrol, evolving hydrogen: but the action is extremely slow, whereas pyrrol is violently attacked by the metal. The slight action in the former case may, possibly, be due to the presence of impurities. On this point I cannot at present speak with certainty, the quantity of liquid in my possession not permitting of a satisfactory solution of it.

In planning methods for obtaining derivatives of pyrrol, it must be borne in mind that the two ethyl compounds just mentioned by no means represent all the different modes of substitution of which the pyrrol molecule is theoretically susceptible. If we apply here the beautiful ideas of Kekulé on the isomerism of benzol derivatives, it will be evident, pre-supposing the correctness of Baeyer's formula, that the introduction into the molecule of any given radicle might give rise to three isomeric bodies, accordingly as it displaced what we may call the imidic hydrogen, or one of either of the pairs of hydrogen atoms adjacent to, and remote from, the nitrogen. Here we have indicated the existence of a large number of derivatives, some of which may yet prove of therapeutic importance. From experiments on which I am at present engaged, in conjunction with my friend Dr. Lapper, it is evident that the toxic properties of pyrrol, which are powerful, are modified in an interesting manner by the substitution of alcoholic groups for its imidic hydrogen. So far our results afford a striking parallel to the interesting observations of Crum-Brown on the physiological action of strychnia and aconitia, and their derivatives. Our experiments shall form the subject of a future communication.

What the precise nature of the relationship which subsists between pyrrol and mucate of ammonia may be, is still obscure. Nevertheless, I think the existence of the compound $C_{12}H_{19}N_3O_2$ is calculated to throw some light upon it. Since this body on heating with alkalies evolves ethyl-pyrrol, we must assume the pyrrol nucleus to exist in it already formed. Its constitution is then most easily explained, if we assume that it differs from diethyl-carbo-pyrrol-amide in containing the group ($CONHC_2H_5$) twice instead of once.

Ethyl-pyrrol.	Diethyl-carbo-pyrrol-amide.	New body.
$C_4H_4N(C_2H_5)$	$C_4H_3(CONHC_2H_5)N(C_2H_5)$	$C_4H_2(CONHC_2H_5)_2N(C_2H_5)$;

and since this view is quite in accordance with its chemical behaviour, I propose for it, provisionally, the name triethyl-dicarbo-pyrrol-amide. Further researches are needed before we can regard this relationship as definitely established; but I think I can show that at least great probability is lent to it, when we collect the results of certain isolated experiments on mucic acid, and endeavour to fit them together.

Fittig,[9] by the prolonged action of hydrobromic acid on mucic acid in sealed tubes at 100° C., has obtained a bibasic acid which he terms dehydromucic acid, and which bears to mucic acid the relation of an anhydride:—

$$C_6H_{10}O_8 - 3H_2O = C_6H_4O_5.$$

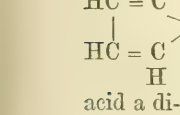
The basicity of this acid compels us to write its formula $C_4H_2O(COOH)_2$, which formula is, moreover, in perfect accord with its behaviour when heated. When its temperature is rapidly raised it breaks up at once, and quantitatively, into the monobasic pyromucic acid and free carbonic anhydride,

$$C_4H_2O(COOH)_2 = C_4H_3O(COOH) + CO_2.$$

Some years ago, now, Limpricht[10] showed that when this latter (pyromucic) acid (which may also be obtained directly by heating mucic acid) is heated with soda-lime, it again parts with CO_2, and yields a very volatile liquid, C_4H_4O, to which the inapt name *tetraphenol* has been applied.

$$C_4H_3O(COOH) = C_4H_4O + CO_2.$$

The characters of this body are such as to show clearly that it does not contain the grouping OH at all; that it is, in fact, neither an alcohol nor a phenol. Limpricht, therefore, assigns to it the formula



acid a di-carboxyl-derivative of this tetraphenol.

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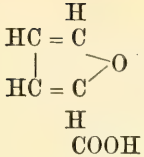
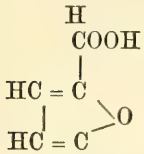
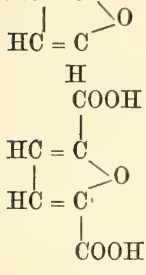
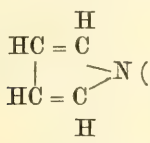
[9] "Berichte der deutschen Chemischen Gesellschaft," ix. 1198.
[10] "Annalen der Chemie und der Pharmacie," band clxv., 253.

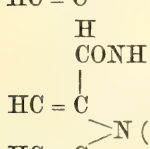

= Tetraphenol.

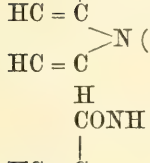

= Pyromucic acid.


= Dehydromucic (Fittig's) acid.

If we now, employing Baeyer's formula for pyrrol, write the three ethyl derivatives, on the view stated above, the relation between them and the tetraphenol derivatives is at once apparent :


= Ethyl-pyrrol.


= Diethyl-carbo-pyrrol-amide.


= Triethyl-carbo-pyrrol-amide.

We have now got the clue to the mechanism of the reactions by which these bodies are obtained from mucic acid. Crum-Brown and Limpricht have both obtained from mucic acid bodies whose formation can only be accounted for on the hypothesis that it (mucic acid) is a derivative of normal adipic acid, the oxidation product of normal hexane, $C_6 H_{14}$. It must then have the constitution—

$$HOOC - \dot{C} - \dot{C} - \dot{C} - \dot{C} - COOH$$

four of the carbon affinities, represented as unsaturated in the diagram, being satisfied by hydrogen, the remaining four by hydroxyl (OH) groups. Of the exact arrangement of these hydroxyl groups we know nothing, but since saccharic acid is with still greater certainty a derivative of normal hexane, it is probably their position which determines the isomerism of the two acids, and consequently of galactose and glucose.

To explain the genesis of tetraphenol and pyrrol we need for the present only consider the OH groups connected with the carbon atoms which lie next the carboxyl groups. These may be supposed to enter into reaction as follows:—

Tetraphenol fragment.

$$\begin{matrix} = C\,(OH) \\ \\ = C\,(OH) \end{matrix} \quad = \quad \begin{matrix} = C \\ \\ = C \end{matrix} > O + H_2O \qquad (1)$$

Ethyl-pyrrol fragment.

$$\begin{matrix} = C\,(OH) \\ \\ = C\,(OH) \end{matrix} + NH_2\,(C_2H_5) = \begin{matrix} = C \\ \\ = C \end{matrix} > N\,(C_2H_5) + 2\,H_2O \qquad (2)$$

If in reaction (1) one COOH group persists, we get pyromucic acid; if both remain, dehydromucic acid is the result. Similarly, if in reaction (2) one COOH group persists, becoming amidated ($CONHC_2H_5$), we get diethyl-carbo-pyrrol-amide; if both, we get the triethyl-dicarbo-pyrrol-amide.

A little consideration will show how the remaining hydroxyl groups could be eliminated from mucic acid, whatever their arrangement may be.

It should be observed that Fittig doubts the connexion of mucic acid with normal adipic acid. But even if it should be shown that one or both of the COOH groups exist as lateral and not as terminal chains, the above explanation will remain, in principle, unaltered.

This would also be the case if it should be found that mucic acid is a derivative of the group—

$$\begin{matrix} - C - C - \\ \\ - C - C - \end{matrix}$$

and pyrrol of the form

$$\begin{matrix} H & H \\ C - & C \\ | & | \\ C - & C \\ H & H, \end{matrix} > N\,H$$

which is by no means impossible.

IV.—On Glaciation by Sea Ice. By Edward L. Moss, M. D. R. N., late Surgeon H.M.S. "Alert."

[Read, January 22, 1877.]

The existence of a glacier implies the co-existence of so many related phenomena, that the integrity of the evidence adduced in proof of it becomes of proportionate importance.

Rounding and furrowing of rock surfaces are amongst the most familiar and characteristic records left by the flow of a glacier, and much attention has naturally been directed to the possibility of similar markings being produced by other causes.

Apart from the planing and striating resulting from agencies unconnected with ice action, and narrowing the subject to the effects of ice alone, it has been very generally admitted that either icebergs, sea ice, or river ice are, under favourable circumstances, capable of rounding off rocks into the "roches moutonnés." On the other hand, much has been written both to prove and to disprove the production of *glacial scratchings* by such agencies.

So long ago as 1847, Forchhammer, writing of the scratched and polished rock surfaces in Denmark, pointed out that sea ice occasionally forced on shore by strong gales carried boulders and *debris* with it, and could hardly fail to striate the rocks over which it passed. Since that time Sir Charles Lyell has referred certain markings found by him in the Bay of Fundy to such action, and Dr. Robert Brown, and Mr. Campbell have dwelt on the probability of its occurrence.

The shore of the Polar Sea in north latitude 82·27, where H. M. S. Alert passed the winter of 1875–76, is everywhere lined with a barrier reef of ice masses broken off from the floes and grounded along the beach in from five to fifteen or more fathoms of water. The ice thus grounded slowly wastes summer after summer from cubical into conical and "mushroom" shapes, and as it wastes it gets forced further and further towards the ice foot by the incalculably great pressure of the Polar pack. It occasionally happens that such masses, during the rough handling they are subjected to every year in the brief disruption of summer, or during the five months in which the floating floes retain some motion, get overturned and thus expose the under surfaces which had lain in contact with the bottom.

Specimens of two such surfaces existed in the immediate neighbourhood of H. M. S. Alert as she lay frozen in her winter quarters. One of them formed the side of an ice cave under a large floeberg half a mile astern of the ship. The ice of the surface which had rested against the bottom was easily distinguished from the clear blue ice round it by the dark colour caused by the mud and fine sand it contained, and every part of it was chiselled into deep and well-marked parallel grooves and ridges, such as, had they existed in rock

instead of ice, would have been considered an excellent example of glacier scoring.

An equally well-grooved ice mass lay frozen into the new floe about seventy yards from our ship's bows and close to the ice-foot. In this instance the grounded floeberg had been all but completely overturned. Three-fourths of the surface exposed above the floe was of clear blue-green ice, worn into the blunt mammillary elevations usual on the under side of old floating ice. The remaining fourth, a space of twenty feet wide by six deep, was, as in the former case, black with mud, presenting indeed a surface not unlike black marble, and was in every part covered by three sets of well-polished parallel grooves—some of them as much as fourteen inches from ridge to ridge.

Two sets of the grooves were almost in the same direction, and passed uninterruptedly across the whole width of the ice. The third existed at one end only, and crossed both the others at an angle of 20°. I have no theory to offer as to the source from which the grooving motion was derived: it was evidently continuous; nothing else could produce such regular grooving twenty feet long.

If the scratching and furrowing had been confined to the ice alone, no proof of actual abrasion would have been forthcoming; and I would have been obliged to refer you for illustration to an excellent photograph taken for the purpose by Mr. White, an officer of H. M. S. Alert, but which I have been unable to obtain in time for exhibition here, from the London Stereoscopic Company, in whose hands the negative was placed by the Admiralty.

The scratchings, however, were not confined to the ice alone, but passed continuously across the surfaces of a number of stones firmly imbedded in the ice and projecting from it in proportion to their hardness. These were chipped out, and I have now the pleasure of exhibiting them. You will observe that several of them show grooves and scratches, which, if their true source had not been known, would have been considered the unmistakable handiwork of a glacier.

In order to avoid any doubt as to the pelagic character of the ice, its chlorine was estimated, and its least salt part was found to contain 0·101 per cent.—a quantity altogether beyond the limits of land ice, and close to the average of the Polar floes around it.

V.—Reports from the Chemical Laboratory of Trinity College, Dublin. By J. Emerson Reynolds, M. D., Professor of Chemistry, University of Dublin.

No. 2.—On the Composition of Lievrite, as determined by Mr. Early's method.

[Read, January 22, 1877.]

Of the several methods which have been devised for the analysis of ferroso-ferric silicates, that which has been published by Mr. William Early,[1] Demonstrator of Chemistry in this laboratory, is probably the most easily managed. The advantages attending its use are chiefly felt in analyzing silicates, which are either insoluble in, or attacked with difficulty by, the ordinary acids; but it can also be used with great convenience in the analysis of silicate easily acted upon by acids.

Lievrite is a silicate belonging to the latter class; and as the formula of the mineral is by no means definitely fixed, I requested Mr. Early to analyze by his method a portion of a particularly fine crystal which I obtained some time ago from the well-known Elba locality, our chief aim being to determine with precision the relative amounts to ferrous and ferric compounds present in the specimen.

The analysis was conducted in the following manner:—

1·54 grm. of the finely and recently powdered mineral was mixed with 20 cubic centims. of hydrofluoric acid (containing 20 per cent. of real acid); and the mixture was boiled for five minutes in a deep platinum crucible with a rather loosely fitting cover. 10 cubic centims. of diluted sulphuric acid (1 part to 2 of water) were then added, and the boiling continued for a few minutes. The contents of the crucible were then washed into a flask with air-free water, and the amount of iron in the ferrous condition determined as rapidly as possible by standard potassic permanganate solution. Another quantity of the mineral was acted upon by strong hydrochloric acid; perfect decomposition was effected, and a gelatinous mass formed; the product was evaporated to dryness, and the silica separated in the usual way. The acid filtrate from the insoluble silica was then saturated with chlorine gas, and ammonia afterwards added in slight excess; the mixture produced was then boiled in a closely covered beaker in order to remove the excess of ammonia, the solution rapidly filtered, and the precipitate collected and ignited with the usual precautions and weighed. The product contained all the iron as ferric oxide, the alumina, the manganese as $Mn_3 O_4$, and a trace of silica. The silica was separated from this mixture by hydrochloric acid; and the filtrate was subjected to the double

[1] "Chemical News" for October 9th, 1874.

treatment with pure caustic soda for the separation of alumina. The iron and manganese were then separated by the baric-carbonate method. From the weight of iron thus found, that previously ascertained to be present in the ferrous state was deducted; the difference represented the weight of metal in the ferric condition. The filtrate from the first precipitate caused by ammonia had the calcium separated from it as oxalate, and the latter was determined in the usual way. The filtrate from the calcium precipitate was then evaporated to dryness, and the residue heated to expel ammoniacal salts; the product of this treatment was dissolved with the aid of a few drops of hydrochloric acid, the magnesium separated by means of baric hydrate and estimated, while the alkalies in the filtrate were converted into chlorides and weighed, and the potassium separated by platinic chloride. No trace of lithium was detected in the mineral.

2·841 grms. of the freshly powdered and unaltered mineral were heated gradually to redness in a hard glass tube connected with a weighed chloride-of-calcium tube; a current of dry air was at the same time slowly drawn through the apparatus. The water collected weighed ·012 grm. =·422 per cent. only.

The percentage composition of the specimen analyzed by Mr. Early may be thus stated, when the metallic and other components are calculated as oxides:—

SiO_2	29·93
FeO	31·83
Fe_2O_3	20·16
MnO	3·02
CaO	13·71
MgO	0·30
Al_2O_3	0·36
K_2O	0·20
Na_2O	0·29
H_2O	0·42
	100·22

These data, when discussed in the usual way, give the following ratios:—

$SiO_2 = 0{\cdot}4983 = 3{\cdot}85 = 4{\cdot}00,$
$RO = 0{\cdot}7431 = 5{\cdot}74 = 5{\cdot}96,$
$R_2O_3 = 0{\cdot}1294 = 1{\cdot}00 = 1{\cdot}04;$

or

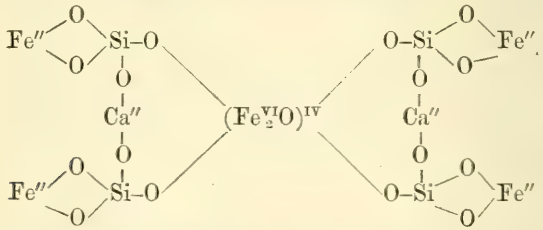
$$R_2O_3,\ 6\ RO,\ 4\ SiO_2,$$

where $6\ RO = 4\ (Fe, Mn)O + 2\ CaO$ nearly, neglecting the small amount of alkalies.

As the water present in the particularly pure specimen of the mineral analyzed did not reach 0·5 per cent., it is difficult to admit, with Städeler, that it enters into the molecule of the compound; I therefore prefer to regard Lievrite as an anhydrous silicate.

Mr. Early's analysis of the mineral agrees in all essential particulars with those of Kammelsberg and von Kobell, though both those distinguished observers found slightly more iron in the ferric condition. A comparison of the analyses of different specimens of Lievrite by Rammelsberg, von Kobell, Städeler,[2] and Early prove that there is little variation in the proportion of Fe^{VI}_{2} to Fe″; I am therefore disposed to regard the former as an essential constituent of the mineral, rather than as a product of the oxidation of a calcio-ferrous silicate. That the mineral oxidizes in time there can be no doubt; but I have had a number of specimens of Lievrite under observation for nearly ten years, and though two of them were placed in a rather damp case, they suffered comparatively slight superficial oxidation.

If, then, we admit that Lievrite is essentially a dicalcic-ferroso-ferric silicate, we can assign to it the following symmetrical formula :—



This formula has at least the merit of indicating that the function of the ferric group is probably one of considerable importance, and that, so far from being regarded as an accidental constituent of the mineral, it ought to be considered one of the most important components of the molecule of the compound.

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[2] See Dana's "System of Mineralogy," 5th edition, p. 296.

VI.—On Experiments to Determine the Influence of the Molecular Condition of Fluids on their Motion when in Rotation, and in Contact with Solids. Report, Part I. By Henry Hennessy, F.R.S., M.R.I.A., Professor of Applied Mathematics in the Royal College of Science for Ireland.

[Read, February 12, 1877.]

Observation and experiment have long since completely established that no fluid can be considered as strictly exhibiting the physical properties of the ideal substance commonly defined in almost all treatises and class-books on hydro-mechanics as a perfect fluid.

In a perfect fluid, the particles are supposed to be free to move among each other by the smallest application of force—in other words, they are supposed to be absolutely smooth, and totally destitute of cohesion. With such qualities, their motions would be free from friction amongst themselves, and almost free from friction when in contact with many solid substances. The practical experience of hydraulic engineers has long since clearly shown, that the flow of liquids is accompanied with very notable resistances, which observers attributed to the friction of the liquids against the surfaces of the vessels and pipes in which they were moving. More recently, mathematicians and physical inquirers have been led to recognise a kind of resistance to the motion of fluids depending entirely on the molecular properties of the fluids themselves, and to this kind of resistance the name *internal friction* has been generally applied. If this term is to continue in use, it appears to me that care should be taken to clearly discriminate between this kind of resistance to motion and that of friction, as it is commonly understood between solid bodies. If two perfectly smooth surfaces of solids of the same form and molecular character are in close contact, as, for instance, two sheets of glass, such great resistance to the motion of one upon the other exists, that portions of them are liable to shear away. The resistance to motion in this case is almost entirely due to cohesion. If two dissimilarly constituted substances be moved in contact, experience shows that when they are very smooth the motion meets with little resistance, but when they are rough, the resistance may be very considerable. In the latter case work must be expended in causing the asperities of one surface to surmount or rub away the asperities of the other, and hence, in some languages, friction is spoken of as synonymous with attrition. We possess no evidence for assuming that such conditions exist between the particles of a fluid as to justify us in classifying the internal resistance to its motion as identical with this kind of force. If we reflect on the phenomena of the molecular statics of liquids presented in the well-known phenomena of capillary attraction, and in the admirable researches of Plateau on masses of liquid free from the

action of gravity, we must conclude that, although the intermobility of the molecules is the fundamental property of all liquids, this property is accompanied by a considerable amount of cohesion. When liquids possess cohesion in a high degree, they are said to be viscid. As far as my observations have gone, I have been led to conclude that the resistance to liquid motion, designated as internal friction, arises almost entirely from cohesion of their particles, and that it might be more simply and more correctly called *viscidity*.[1]

The paramount influence exercised by the motions of fluids in many of the most remarkable phenomena of nature has long since induced observers to undertake experimental researches with reference to the resistances of fluids. Coulomb[2] was the first who made systematic experiments with a view to elucidate the influence of cohesion on the resistance of fluids. His researches appear to me to have been chiefly directed to the examination of the resistances experienced between the surface of a moving solid and a fluid in contact. Similar experiments have been more recently performed by Meyer.[3] Helmholtz[4] and Pietrowzki have carried on experiments with a notably modified method.

In the two first of these inquiries the experiments were conducted by causing a solid horizontal circular disk immersed in the fluid to undergo periodical oscillations around a vertical axis. In the third, the fluid was included in a solid globe, which was subjected to periodic oscillations. In order to deduce from the facts of observation in these cases any results as to the external or internal resistance of the fluids, elaborate mathematical theories are indispensable. In the latter case especially, the oscillations of the hollow globe produce waves whose motions complicate the phenomena so as to require complex formulæ for their expression.

Among the phenomena in which the internal resistance of fluids may be important, those where liquids are in rotation about an axis seem to be more simple than where they are undergoing large oscillations, and it thus occurred to me that an experimental study of such a motion of fluids might prove fruitful in results. From the nature of fluids it seems likely, whatever precautions we may take, that even the most simple kinds of motion of their particles cannot take place with great rapidity without the production for a time of some kind of oscillation. But the results will probably be less complicated than

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[1] The floatation of small solids of greater density than the liquids on the fluid surface shows that the cohesion of the particles of liquid among themselves may be sometimes accompanied by repulsion for solids. I have already brought under the notice of the Academy some remarkable phenomena of this kind, in which the cohesion of the liquid particles for each other was clearly illustrated, as well as their repulsion for the small solid bodies.—"Proceedings of the Royal Irish Academy," vol. i., series ii., p. 153.

[2] "Mémoires de l'Institut National," tom. iii.

[3] Poggendorfs "Annalen," vol. cxiii., p. 55.

[4] "Sitzungsberichte der kais. Academie zu Wien," vol. xl.

when such oscillations are purposely produced, as was done in some of the experiments to which reference has been made.

The researches on the motions of liquids which I have commenced are intended to elucidate the phenomenon of fluids in rotation, under varying conditions. I was led to study the matter, chiefly from its bearing upon a question regarding the structure of our earth and the other bodies of our planetary system. Among astronomers and mathematicians the figure of the earth had been long required as a standing proof that it was originally in a fluid state. The arguments of Playfair and Sir John Herschel to account for this figure by the abrasion of a solid globe under the action of denuding forces have been long since shown by me, in a communication to this Academy,[5] to lead to results entirely inconsistent with observation. The results of my calculations on this point have been subsequently confirmed by other mathematicians, and the question seems therefore to be finally at rest. But although the primitive fluidity of our planet seems now to be universally admitted, doubts have been put forward as to whether any great portion of its interior is yet in a fluid state. As this is obviously a question of the highest importance in geological theory, and in any attempts at accounting for the phenomenon of earthquakes and volcanos, its solution has long been under discussion. The idea occurred to the late Mr. Hopkins, of Cambridge, that if the greater part of the earth's interior were fluid, the resulting motions of the earth's axis known to astronomers as precession and nutation might be different from what would take place in a perfectly solid spheroid. He investigated the problem mathematically, with the aid of the usual equations of hydro-dynamics and the equations of rotation. His conclusions were that the earth was chiefly, or almost wholly, solid. His formulæ were deduced upon the supposition that no friction, or resistance, existed between the solid and fluid parts of the earth, and that no internal friction existed in the fluid. In the words of Archdeacon Pratt, "The success of the calculation depends upon a remarkable result at which he has arrived, that the precession caused by the disturbing forces in a homogeneous shell, filled with homogeneous fluid, in which the ellipticities of the inner and outer surfaces are the same, is the same, whatever the thickness of the shell. It is, therefore, the same for a spheroid solid to the centre." I am now enabled to say, that if Mr. Hopkins' hypothesis of a fluid with particles entirely destitute of resistance to their own motions, and without friction against its solid envelope, be adopted, the result alluded to by Pratt can be obtained by a very simple analysis. I hope soon to be able to submit such a proof in another paper. The result is one of some importance, for, combined with another to which I had been led, it shows that the earth cannot be entirely solid, and that it is, for the most part, a mass of fluid contained within a shell of unde-

[5] "Proceedings of the Royal Irish Academy," vol. iv., series i., p. 333.

termined thickness. At the same time, it follows that this fluid must have properties entirely different from the ideal fluid assumed in Mr. Hopkins' inquiries. I was led to affirm, that the fluid matter of the interior of the earth possessed such an amount of viscidity as to cause it to rotate together with its solid envelope, as if they constituted one continuous mass.

Several years afterwards, by a very simple process of reasoning from physical and mechanical principles, M. Delaunay was led to announce precisely the same conclusions with reference to the motions of the solid and fluid parts of the earth. So remarkable a confirmation of my views created much discussion, and some of those who had adopted the conclusions of Mr. Hopkins seemed to call in question the physical properties of fluids alluded to by M. Delaunay and myself. The properties in question are the outward resistances of fluids to solids in contact with them, and the internal resistances among the fluid particles, when both the fluids and solids are rotating. It is scarcely necessary to say, that the phenomena of fluids in rotation are connected with other physical questions, and they have a most important connexion with questions of the practical application of hydro-mechanics. Hence I may be permitted to hope that the inquiry I have commenced may be attended with some useful result.

The first experiments I tried were similar to those quoted by M. Delaunay, and made, under his direction, by M. Champagneur.

I obtained a small glass globe, which could be more or less filled with liquid by a small opening. A strong silk cord was looped round the region of its equator, and to the opposite sides of this cord a pair of silk threads were attached, which were fastened to a support close to the ceiling of a lofty room. A steady and rapid rotation was communicated to the globe by the torsion of the threads. I half filled the globe with common water, and placed a number of small pieces of paper of the same size on its surface at different distances. Whenever the globe was set in rapid rotation, the pieces of paper were at first left behind, and therefore the water; but when the rotation was long continued, the papers appeared to move at the same rate. If the rotation was slow from the commencement, the papers seemed to move with precisely the same angular velocity as the glass globe. With moderate velocities, if a piece of paper was placed in the centre of the flat surface-hemisphere of water, it required some time to partake of the motion of the vessel, but if placed near the glass it immediately moved.

However instructive these experiments were, they could only be regarded as preliminary inquiries, suggestive of ideas to be tested by more precise methods.

I accordingly, with the assistance of the well-known mechanician and instrument-maker, Mr. Spencer, devised an apparatus which might be employed in the study of phenomena accompanying very slow rotation of fluids or rapid rates of motion. I was particularly desirous of being able to observe the effects of the internal viscidity of liquids by

which the motions of successive strata of the same liquid influence the adjoining strata. On this account I have not employed the arrangement used by Coulomb, and subsequently applied by Meyer, as the direct results which that arrangement gives refer more immediately to the resistance of a solid surface moving against the liquid. Results as to the internal viscidity have subsequently been deduced indirectly from the observations thus made.

As the object of these experiments has been to study the phenomena accompanying the rotation of liquids, a steady rotating motion was indispensable. For this purpose I had a clock specially constructed, which worked by a gearing of toothed wheels, so as to move a vertical axle carrying on it a very strong wooden disk, to which another exactly similar could be fastened by screws. On the latter was fixed a broad socket of hard wood, with a large hollow screw cut deeply within it. The vessels employed were glass, and each carried at bottom a broad solid screw of hard wood firmly attached by cement. In this way the most complete union between the vessel containing the liquid and the rotating support was obtained. The clock was driven by two powerful springs, and was regulated by a pendulum when slow motions were required. A fan with movable pallets was employed as a regulator for rapid motions. The whole was supported by and firmly bolted to a low flat table of wood. The circular disks are furnished with a slotted arm and clamping screw which permits the axis of the vessel containing liquid to be inclined at an angle to the axis of rotation. The vessel which was principally employed is of glass; it has a bell-shaped bottom and cylindrical sides. Around the cylinder a slip of paper, divided into 360 equal parts, was rolled in such a way as to be in the plane of the circle forming the cross section, or in a plane parallel to the surface of the liquid when at rest. In order to observe the relative motions of the liquid and the containing vessel, a strong rectangular frame was fixed to firm supports placed outside the table already mentioned, but not touching it. The cross piece had a slot which permitted a small brass crotchet to be screwed down vertically, after being shifted until it was placed over the centre of the vessel. In this crotchet is a small slit which could be closed by a screw. From the crotchet an indicator was suspended by a fibre of unspun silk, such as is usually employed in galvanometers. The indicator consists of two fine slips of light wood (deal), fastened with strong thread at the ends and half way from the axis. At the axis a piece of very fine platinum wire was looped, and terminated in a small hook, to which the suspending fibre of silk was attached.

The slips of deal were graduated in centimetres, from the centre of suspension outwardly.

Between the two slips of deal two equal and rectangular thin laminas of mica were inserted; these laminas were always placed at equal distances from the point of attachment of the suspending fibre by the aid of the graduation above mentioned. Before making the

experiments, the indicator and its mica plates were always perfectly balanced.

Up to the present, water has been the liquid exclusively employed. I have sometimes used the common water supplied from the water-works, but recently, distilled water. In making the experiments, great care was necessary in the introduction of the mica plates into the water. If water was a perfect fluid, the introduction of such slender disks would be accompanied by no sensible resistance, but this was so far from being true, that unless both plates were plunged into the liquid at the same time, and to almost equal depths, the equilibrium of the indicator became totally deranged by the difference of the resistance experienced by these disks plunged edgeways. After they had been plunged into the liquid, and allowed to adjust themselves, it was manifest that each disk exercised attraction on the adjacent liquid, from the concave meniscus of liquid heaped up at each side. But this is precisely what is desired, for we wanted an indicator moving as much as possible with the liquid, and immediately partaking of its changes of velocity.

If the air contained in the vessel were absolutely at rest during the rotation, it would resist in a slight degree the motions of the wooden cross-bar and of the pieces of the mica disks above water; but as it is certain that air is endowed with some viscidity, or, as some prefer to call it, internal friction, it must partake in some measure of the motion of the vessel. If it did not, its tendency would manifestly be to keep the indicator in its original place. In this case the moving force acting on the indicator would be that of the strata of liquid pressing against the mica disks, and the resistance, that of the air in which the indicator was partly plunged. From the weight and dimensions of the wooden indicating bar and the mica disks, which I have already given, it is evident that the moment of inertia of the whole is very small, and as yet I have not deemed it necessary to calculate its exact amount. In reducing the results of observation, in order to determine numerical co-efficients for the friction of the fluids against solids, or for internal viscidity, this moment must be estimated.

The apparatus for making the experiments being adapted for working with very slow or rapid motions, it has occurred to me to divide the investigation into two parts. The first refers only to the phenomena of slow rotation. By the adaptation of the pendulum, the vessel containing liquid has been made to revolve at velocities of from about one turn in two hours and a half to one turn in four hours, or six turns in a day.

The method of observation adopted was the following: The vessel was filled with water to a depth of twelve centimetres, which enabled the mica disks to plunge three centimetres into the liquid, leaving one centimetre between the surface of the liquid and the indicating bar. After this had come to perfectly steady condition, the positions of the mica disks were sighted on the graduated circle, and when the sus-

pending fibre had been properly centred, both disks were found at 180° distance. The clock having been previously wound up, it was now set in motion. When the rate was one turn in four hours, it was easy to observe the positions of the disks at short intervals as well as after stopping the clock at the end of a few hours. In this way a small angle of deviation of the disks with reference to the cylinder would be instantly detected. As the arrangement permitted the placing of the disks at different distances from the axis of rotation, the position of the centre of each disk was accurately measured before each experiment. In all the recent experiments with very slow rotation, I have employed distilled water, and the temperature of the room was maintained by hot water arrangements nearly constantly at about 62° Fahrenheit.

EXPERIMENTS WITH SLOW ROTATION.

No.	T.		A.	B.	V. of R.
1	2 hours.	Distance of centre disks from the axis of rotation, 9 centimetres, ..	316°	316°	1 turn in 4 hours.
2	51 mins.	Disks at the same distance, ...	314	314	
3	4 hours.	Disks at the same distance from axis, ...	316	316	
4	11 hours.	,, ,, ..	316	316	
5	4 hours.	,, ,, ..	316	316	
6	1 hour.	Disks at 6 centimetres from axis of suspension,	348½	349	
7	10 hours.	,, ,, ..	349	349	
8	1 hour.	Disks at 4 centimetres from the axis, ..	90	90	
9	..	Disks at 9 centimetres, ..	106	105	1 turn in 2 hrs. 36 min.
10	1 hr. 40 min.	Disks at 6 centimetres, ..	86	85½	Same velocity.
11	3 hours.	Disks at 6 centimetres, ..	83	83	

T. means duration of experiment. A. position of index at the beginning, B. at the end. V. of R. velocity of rotation of the containing vessel.

Of the experiments with rapid rotations, the only result which, I think, may be mentioned, is one bearing upon those obtained from

slow rotation. When the vessel rotated once in thirty, or even in twenty seconds, after an interval of about seven minutes the indicator moved with the same angular velocity as the vessel. When the mica plates had been long immersed in the water, this interval was reduced, showing that the water took time to completely adhere to the mica.

As the radius of the vessel is 132 millimetres, the disks were plunged in water at 42 millimetres from the glass sides in experiments 1, 2, 3, 4, 5, and 9. They were at 72 millimetres in experiments 6, 7, 10, and 11, while in experiment 8 they were at 92 centimetres from the glass. In this way they enable us to observe the relative velocities of the strata situated at very different distances. Yet in all of these observations, from the moment when rotation commenced until its conclusion, the index continued to steadily point to the graduated circle. The adherence of the water to the mica disks was all along distinctly manifest. The water also adhered to the glass at the sides of the vessel, and all through the fluid the adjacent particles were attracted to each other. With slow velocities of rotation, these actions seemed to suffer no disturbance: each successive stratum of water, from the sides of the vessel to the mica plates, revolved with precisely the same angular velocity, and thus the vessel and its contained liquid rotated as one mass.

Besides the experiments recorded in the foregoing Table, I have made several others with slow and quick velocities; the former all lead to the same result as those recorded, and I reserve the discussion of the latter for the second part of my Report. The observations I have already made, and those presented by other inquirers, clearly establish that natural fluids possess internal viscidity to such an extent as to vitally influence conclusions drawn from the mathematical treatment of problems in hydro-mechanics. Capillary phenomena, where the molecular action of solids and liquids at small distances is so strikingly manifested, appear to have led to the notion that, because large and *uncapillary* vessels do not clearly manifest such actions, the motions of liquids within them could be considered as independent of molecular action. But the force of cohesion, from particle to particle, exists throughout the whole of a mass of liquid, no matter how great, and hence its motions are governed by the specific amount of this force. It is singular that the idea of what is called a perfect fluid should be so constantly in the minds of mathematicians who have treated hydro-mechanical questions, when one of the best-known elementary problems implicitly supposes a totally different fluid property. A cylindrical vessel containing liquid is set into very rapid rotation: required the shape of the concave surface of the liquid. The ordinary equations of hydro-dynamics are used for solving the problem, but the hypothesis is made that the angular velocity of each particle of the liquid is the same. This could not be true in a perfect liquid. The cylinder would tend to slip past the particles close to it, and if these acquired any velocity from the roughness of the cylinder, the

adjacent internal strata would remain undisturbed. When the experiment is actually made, the observed and calculated form of surface agree very well. But this arises because the whole fluid possesses internal viscidity whereby each stratum has a grip on that which it encloses, and it cannot rotate without pulling the other.

A mathematician, to whom allusion has been already made, is reported to have declared that the conclusion I put forward, as to the interior fluid of the earth and its containing solid shell rotating as one mass, is "a mechanical impossibility." In making this remark, he had in view the purely ideal substance called a perfect fluid. The experiments I have already made seem to show that, for a natural fluid, the phenomena of its rotation are in harmony with my conclusions, and widely different from those of the ideal substance commonly defined as a fluid in connexion with mathematico-physical theories. In the course of the discussion on the precessional motion of the earth considered as a solid shell enclosing a mass of fluid, it was asserted that the slowness of the precessional motion had nothing to do with the relative velocities of the shell and its contained liquid. The experiments I have made show, on the contrary, that the relative velocities are closely dependent upon the absolute velocity of the solid envelope, and when this moves slowly the liquid is carried along with it as if the whole were one mass.

VII.—On Revival of Manuscripts on Parchment. By R. Angus Smith, Ph. D., F. R. S.

[Read, February 26, 1877.]

Having attended occasionally to the manuscripts sent to me by Dr. Ferguson, although I am not able to say that I have finished my work, it may be well to give the results up to this time. I began with the fullest ignorance, and tried methods long since tried; and I fear that, even now, I am able to speak only of modifications of old plans. Still, as I am not aware that any one has obtained equally good results, I shall venture to send the following with a hope that it may be thought worthy of being laid before the Royal Irish Academy.

I tried, as many people have done, tannin, and find that it acts very differently on different parchments. In one case it was fixed with mastic varnish, and a manuscript of a perfectly illegible character has been thus rendered clear and bright. I am not, however, sure that it is unaltered after a year.

With sulphide of ammonium magnificent dark colours were obtained, but it is not easy to dry the ink before it becomes oxidised, and the dull brown returns. Still I have preserved one manuscript of this kind with mastic varnish, and a part with paraffin, very bright for a year.

I think these processes might be used so that the brightness, if temporary, should give good photographs. They are, however, only imperfect processes. The preservation I found much facilitated by moistening the parchment with water until it was quite soft, and then mounting it on card board. This plan has never, to my knowledge, been adopted with skins, but it seems to answer perfectly. It preserves, at least, one side from the action of the air, and the varnish preserves the other. The back of the paper could also be varnished.

This is a question which requires to be reviewed from many sides, and it is a new one to me, so that I do not say much as yet.

The use of ferro-cyanide of potassium very naturally occurs to a chemist, and it was with this salt I obtained the best results; it was, however, used acid. Hitherto this has not been the case, and I believe a certain destruction of the organic matter of the ink may have taken place without a corresponding deposit of the iron compound. The acid first used was acetic. After having, in the usual way, used solutions which produced results which, to say the least, could not be regarded as final, it was with very great surprise that I saw the whole parchment become white as new, and in all probability much whiter than ever it was before. The dark-brown, dirty, and crumpled parchment, with illegible marks, was like a sheet of white paper with writing perfectly clear and sharp, and when laid on a board, still in a moist state, it was smooth also. This I thought a great triumph, but it

occurred to me that the action was only superficial, and that the colour would go deeper when it was longer exposed, but to my grief this did not take place, but the ink began to fade. Seeing this, the parchment was washed, then well gummed behind, and put on a smooth board so as to be photographed. The writing was bright enough still, but had lost its original brilliancy, and as the original and the photograph are in your hands, you can judge of the results. [Since writing the above the whiteness has diminished.]

The diminution of colour was a disappointment; on considering that the ferro-cyanide of iron was found by Graham to be soluble, but very slowly, in oxalic acid, it was imagined that it might be so in acetic. Graham, however, did not find this. Still we must take the result. To avoid this difficulty, then, it was needful to try another acid, and I took common sulphuric. I had no MS. of the untouched kind to try upon, and I have used only scraps of some which had failed with other processes; but there I find, so far, a confirmation of the belief that, by allowing the writing to remain longer, it would take up more of the solution, and darken by being penetrated. One, after eight days' immersion, was darker than ever, and that point is apparently settled. But, on the other hand, the skin was not whitened: true, but it was a skin that had been so much tortured with chemicals previously, that one need not be surprised. I tried also neutral solutions with varying results. A good deal depends on the ink and the quality of parchment.

Now, I am in this position: I have a belief that the process might be perfected by various modifications, but I have no material on which to work. I believe there are many old parchments quite useless, and on some of these I am desirous of continuing the trials. This class, probably, does not exist in the Academy, but is found chiefly among papers of lawyers. Of course it would not be right to make any experiments on MSS. with ancient literature of any kind or on very old MSS., but there are trifles in abundance.

The chief novelty in this process is the clearing of the ground. It often happens that the ink is dark enough, but being equalled by the darkness of the ground, nothing is seen; the absolute whitening of the ground makes the faintest shade of the remaining ink visible, and all we require to do is to use a compound which will not dissolve the ink.

For MSS. which are not written with ink prepared with iron salts, but with carbonaceous inks, this process would be perfect, as the ferro-cyanide does not act on carbon. Where the writing or painting is oleaginous, the clearing up of the surface will restore the original ground; but without affecting the characters or lines either for good or evil, it will throw them into the fullest contrast. I do not know if any MSS. are of this kind in this country.

If there be nothing to bind the colour; if, for example, there should only be the remains of a water-colour writing or drawing, the use of a watery solution will, as a matter of course, be an objection.

It would be difficult to use the process for paper, because a large amount of liquid is required, the solution not being merely painted over, as in the old process.

[*Note added February*, 1877.—I wrote this in January, 1876, and after a year I send it, but having done nothing, there is nothing to alter.]

VIII.—Reports from the Observatory of Trinity College, Dublin. By Robert S. Ball, LL. D., F. R. S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.

No. 1.—On the Method of Regulating a Clock intended to show Correct Mean Time.

[Read, February 26, 1877.]

In the following note I describe the method which I have adopted for the regulation of the new mean time clock erected by Messrs. Booth, of Dublin, at the Observatory of Dunsink. This clock controls an electric current, which goes from the Observatory to Dublin, for the purpose of regulating the clock in the Port and Docks Office of Dublin to correct Dublin time.

In the regulation of the clock the object to be attained is to make the clock show correct time directly. In other words, we try to have the error of the clock always small. The method I have employed is the well-known one of applying small correcting weights to the pendulum at the centre of its length. It is possible, however, that the following description of the way to make this correction in a systematic and orderly manner may be of use :—

It was found, by experiment, that a weight of 635 milligrammes, placed upon the "shelf," which is fixed on the pendulum rod at the centre of its length, increased the rate of the clock one second per diem.

I shall suppose that the error of the mean time clock is to be determined every day at mean noon by comparison with the astronomical clock.

Suppose that yesterday at noon the error was E', and that to-day at noon the error is E, the rate of the clock is therefore $E - E'$, and consequently the error at noon to-morrow would be $2E - E'$. If, therefore, we wish to have the clock right at noon to-morrow, a number of weights equivalent to $2E - E'$ must be added to or taken from the shelf at noon to-day. The principle of the correction is that, by comparison of the errors of noon to-day and noon yesterday, we endeavour to make the clock right at noon to-morrow.

In the practical application of this method we may assume that we never have to deal with a clock more than two or three seconds wrong, and under these circumstances the correction may be made with the greatest facility.

We shall assume that half a second is the smallest portion of time of which it is necessary to take cognizance. The following Table will then tell us at once how many weights should be placed on or taken off the shelf:—

Seconds of Mean Time Clock at True Mean Noon Yesterday.	Seconds of Mean Time Clock at True Mean Noon to-day.								
	58·0	58·5	59·0	59·5	0·0	0·5	1·0	1·5	2·0
58·0	+ 2·0	+ 1·0	+ 0·0	− 1·0	− 2·0	− 3·0	− 4·0	− 5·0	− 6·0
58·5	+ 2·5	+ 1·5	+ 0·5	− 0·5	− 1·5	− 2·5	− 3·5	− 4·5	− 5·5
59· 0	+ 3·0	+ 2·0	+ 1·0	0·0	− 1·0	− 2·0	− 3·0	− 4·0	− 5·0
59·5	+ 3·5	+ 2·5	+ 1·5	+ 0·5	− 0·5	− 1·5	− 2·5	− 3·5	− 4·5
0·0	+ 4·0	+ 3·0	+ 2·0	+ 1·0	+ 0·0	− 1·0	− 2·0	− 3·0	− 4·0
0·5	+ 4·5	+ 3·5	+ 2·5	+ 1·5	+ 0·5	− 0·5	− 1·5	− 2·5	− 3·5
1·0	+ 5·0	+ 4·0	+ 3·0	+ 2·0	+ 1·0	0·0	− 1·0	− 2·0	− 3·0
1·5	+ 5·5	+ 4·5	+ 3·5	+ 2·5	+ 1·5	+ 0·5	− 0·5	− 1·5	− 2·5
2·0	+ 6·0	+ 5·0	+ 4·0	+ 3·0	+ 2·0	+ 1·0	0·0	− 1·0	− 2·0

For example, at mean noon to-day the clock showed 11h. 59m. 59·0s., while yesterday it showed 0h. 0m. 0·5s., then the table gives + 2·5, which means that weights equivalent to 2·5 seconds should be placed on the shelf, to make the clock right to-morrow.

In order to facilitate the application of this correction fifteen cylindrical brass weights have been made. These cylinders have weights corresponding to 3, 6, 9, 10, 10·5, 11, 11·5, 12, 12·5, 13, 13·5, 14, 14·5, 15 seconds respectively.

In starting the clock, it is rated by the pendulum bob, in the usual way, to go as nearly accurately as possible when the 12·5 second cylinder, and also the 6 second cylinder are both on the shelf. The latter will not be altered, unless in the case of a considerable change

in the clock-rate, when it may be replaced by the 3 or the 9. The ordinary daily correction is simply made by changing one of the cylinders for another. Thus, to take an example—

Suppose that to-day the clock showed 59 seconds, that yesterday it was correct, then the Table gives + 2. If, then, the cylinder 11·5 were on the pendulum, it should be removed, and 13·5 put on instead. It will, however, occasionally happen that the required correction is beyond the reach of the change which could be effected by one cylinder. It would be so in the instance just given, if the cylinder 13·5 had been on the shelf, instead of 11·5. The correction would then require a cylinder of 15·5. In this case the cylinder 6 is removed, and 9 put on instead, and then the cylinder 12·5 seconds is put on. The second cylinder is thus only required for *secular* corrections, as it were; the ordinary daily correction is effected in a moment by the extremely simple process of changing one cylinder for another.

The cylinders are very readily removed, without deranging the pendulum, and the number appropriate to each cylinder is engraved upon it.

Although this method may seem, in describing it, to be somewhat complicated, yet it works with the greatest facility, and leaves nothing to be desired on the score of precision.

IX.—PROOF OF HAMILTON'S PRINCIPLE OF VARYING ACTION. By PROFESSOR TAIT; Communicated by DR. BALL.

[Read, April 9, 1877.]

WE have as usual,

$$T + V = H,$$

$$A = 2\int T dt,$$

$$\delta A = \int (\delta T + \delta H - \delta V)\, dt$$

$$= \Sigma \int \left(\frac{dT}{d\theta}\, \delta\theta + \frac{dT}{d\dot{\theta}}\, \delta\dot{\theta} - \frac{dV}{d\theta}\, \delta\theta \right) dt + t\delta H$$

$$= \Sigma \left\{ \left(\frac{dT}{d\dot{\theta}} \right) \delta\theta \right\} + t\delta H$$

$$+ \Sigma \int (\text{terms disappearing in consequence of Lagrange's Equations of Motion})\ \delta\theta dt,$$

whence of course

$$\frac{dA}{d\theta} = \frac{dT}{d\dot{\theta}}, \text{ \&c.,}$$

$$\frac{dA}{dH} = t,$$

which is the essence of Hamilton's varying action.

X.—Laboratory Notes.[1] By Charles R. C. Tichborne, Ph. D., F. C. S., &c.

No. 6.—On the Formation of Magnetic Oxide by the Dissociation of Ferrous Salts.

[Read, April 23, 1877.]

In the description of a find of magnetic iron ore in Wicklow, which I read before the Royal Geological Society of Ireland, I lately offered some suggestions as regards the processes by which these deposits were formed in such localities; the stratified appearance of the ore, taken in connexion with its associated minerals, at once putting out of question the idea of this magnetite being of igneous origin. There was, however, undoubted evidence of the ore being the result of the oxidation of pyrites into sulphates of the base. Presuming that there is no limestone in this district, it becomes necessary to suppose that the deposition of Fe_3O_4 was determined without the aid of a precipitant. At the time of my reading the Paper to which I have referred, I exhibited a tube, which originally contained a partially oxidized solution of ferrous sulphate (a solution of ferrous sulphate which had been exposed to the air for some twenty-four hours). On submitting this tube, when sealed, to a temperature considerably above the boiling-point of water, magnetic oxide was deposited, apparently in the anhydrus state. On repeating this experiment lately, with definitely oxidized solutions, to my great surprise I got nothing but an anhydrus red precipitate of ferric oxide, perfectly destitute of magnetic properties. I therefore instituted experiments to determine the conditions under which Fe_3O_4, would be deposited.

A mixture was made, which, on precipitation, would give us the molecule FeO, Fe_2, Fe_3, or one in which two-thirds of the solution had been oxidized up to the ferric condition. On heating this solution nothing but ferric oxide was formed.

In one case half the solution had been converted into a ferric, and half left as a ferrous salt. Such a solution contained the elements of an oxide $2FeO, Fe_2, F_3$. Only peroxide of iron was obtained in this case also, even after prolonged heating at a very high pressure in sealed tubes. As I thought that the basicity of the solutions might determine the deposition of the magnetic oxide, both of the above solutions were rendered so basic that the slightest application of heat would determine a precipitate on heating. On submitting them to a very high temperature in sealed tubes the deposits were not magnetic, and, therefore, we must come to the conclusion that, owing to the easy dissociation of ferric oxide, that oxide is deposited first, and that the acidity of the solution produced by this act of dissociation is sufficient to keep the ferrous oxide in solution. There is no doubt that a

[1] Continued from vol. ii., series ii., p. 84.

point would ultimately be reached where the dyad iron would be deposited if we could get tubes sufficiently strong to stand the pressure, but they invariably burst. The presence of alkaline salts, although they facilitate the deposition of basic precipitates, did not in this case determine the formation of magnetic oxide.

A solution of ferrous sulphate was allowed to remain exposed to the air for some time until partially oxidized. The resulting solution was then placed in a sealed tube, and on the application of heat it immediately deposited the magnetic oxide, and apparently in a larger proportion than what would be deposited from the small amount of trioxide formed. We, therefore, see that mixtures such as would give the oxide Fe_3O_4, on precipitation by an alkali, or alkaline earth, do not give magnetic oxide when submitted to the dissociative action of heat, or at least they do not do so under the pressure that we are enabled to bring to bear. But we also find that partially oxidized solutions of ferrous salts, containing 10 to 20 per cent. of the ferric oxide, do deposit magnetic oxide, on submitting them to heat under pressure, although such a solution on being left exposed to the air would not deposit anything but ferric oxide. Even if a ferrous salt is directly precipitated, in time the ferrous oxide is formed, but never the intermediate magnetic oxide. On the application of a temperature above 100 C., magnetic oxide is deposited from solutions which are slightly oxidized.

Assuming that pyrites is the origin of this vein of magnetic ore, we should get by the weathering action of the air a solution which would exactly answer all these requisites—a ferrous sulphate partially oxidized, and in a basic condition. Magnetic oxide is found extensively diffused, and in immense masses, in all parts of the world. It can be formed by igneous action, and is no doubt frequently formed by the precipitating action of alkaline earths; but there are certain deposits which from their character do not point to either of those methods; and I have, I think, supplied in this note a description of one of the methods by which magnetite is sometimes formed in the laboratory of Nature.

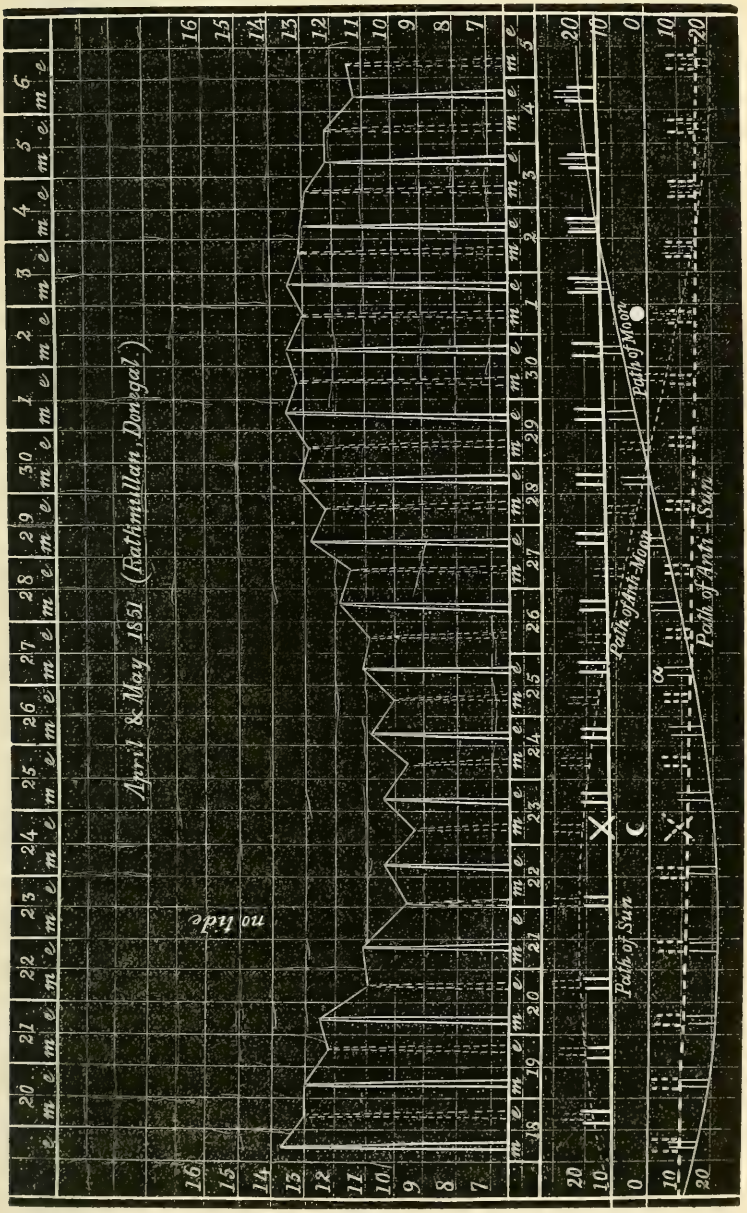
XI.—Observations on the Phenomena of the Tides as Observed at Fleetwood (Lancashire), with Illustrations from the Tides of Rathmullan (Co. Donegal). By the Rev. James Pearson, M.A., Cantab., Ex-Scholar, Trinity College, Cambridge.

[Read, May 14, 1877.]

Having been for some time engaged in making observations upon the tides at Fleetwood, I wish to place on record some of the theoretical results to which I have been led, as well as to say a few words in reference to a graphical construction which I have found very convenient for illustrating the relation between cause and effect in their production. The most elementary knowledge on the subject teaches us that the elevation of the tides is due not only to the action of the moon and sun on the waters immediately below them, but also that this action is extended directly through the solid body of the earth to the waters on the obverse side of it. The effect may in part be conceived by supposing two moons, one on each side of the earth, the line joining them always passing through its centre, and each attracting, so as to produce on its own side the tide actually exhibited. The first of these being the real moon—the second, or fictitious one, may be called the "anti-moon." In the very same way, we must imagine the tides which are produced by the sun to be of the same twofold character. We are thus introduced to four sets of tides, each, as it will be seen, operating under extremely different circumstances, namely—1st, a *lunar* tide, swelling under the direct action of the moon; 2nd, an *anti-lunar* tide, swelling under the obverse action of the "anti-moon;" 3rd, a *solar* tide, generated under the direct action of the sun; and 4th, an *anti-solar* tide, due to the direct action of the "anti-sun." A little reflection will serve to make it apparent that when the true moon is seen in the northern hemisphere or has *north declination*, the fictitious "anti-moon" or "anti-sun" is over the southern hemisphere, or has *south declination*. More than this, it will be seen that as either of these luminaries advances from *south* to *north* declination, its fictitious antagonist will recede from *north* to *south* declination, and *vice versâ*. But forasmuch as land predominates in the northern, and water in the southern hemisphere, the magnitudes of the tides produced will, from this cause alone, be very different, and when the resulting tides, which are formed of the superimposed tides due to the attractions of the sun and moon, consecutively arrive at our shores, they will display this difference of magnitude very prominently.

Now, to this point I wish to call particular attention. Theoretically, "the action of the moon produces a tidal spheroid; and the protuberances of this spheroid may be considered as composed of two tidal waves—one following the moon, and the other opposite to this. When the sun and moon are not in the equator, one of these may be called the northern, and the other the southern tidal wave. Now, places in the northern hemisphere pass nearer to the pole of the northern tidal wave, and places in the southern hemisphere nearer to the pole of the southern; and hence the tides are alternately greater and

less. The greater tide when the moon has north declination, the lati-



tude being north, will be the superior tide, or that at the third lunar

hour; when the moon's declination is south, this will be the smaller tide." This is precisely what theory advances (see "Whewell's Dynamics," part i., ed. 1832, p. 198); and I am not aware that the true theory, as it is called, which is based on the Harmonic Analysis of the Tides contradicts the more anciently-received one. But, in point of fact, and as the result of observation, the configuration of land and water is such as to cause that tidal wave, whose pole is, or ought to be, in the northern hemisphere, to be *invariably* of *lower* magnitude than that whose pole is in the southern hemisphere; and, as I take it, the simple reason of the contrariety is, that neither moon nor sun can possibly generate a tide in regions where little or no water exists for the purpose.

What observation shows is this—that the *lunar* tide is greater than the *anti-lunar* which follows it, whenever the moon's declination ranges from 20 deg. S., *ascending* to about 15 deg. N. *ascending;* and the *anti-lunar* tide is greater than the *lunar* whenever the moon's declination ranges from 20 deg. N., *descending* to about 15 deg. S., *descending;* the parallax being the same throughout.

A few words must be added in explanation of the accompanying diagram. The figures at the side denote the successive feet as marked on an Admiralty Tide-gauge, whose base is the mean level of low water of ordinary spring tides. The figures at the top of the page point out the days of the month during which the observations were made, and the letters "*m*," "*e*," refer to the morning or evening tide, as the case may be. The figures in the middle of the diagram refer also to the days of the same month, but each of them is put a day and a-half antecedent to those in the top line, because there is that interval from the "transit B" of Sir John Lubbock, during which the tide travels from its cradle in the South Pacific to the Irish Sea. The tides are marked alternately by dotted and by straight lines, the latter indicating what we have called *lunar*, and the former *anti-lunar* tides, and they are laid down to scale, thus showing by the lines joining the summits the course of the curve they form. Within the space at the lower part of the diagram, the moon's path and that of the sun are plotted also to scale, and the dotted lines show those of the "anti-moon" and "anti-sun." A glance from the top to the bottom of the diagram, in the direction of the lines which mark each tide, enables us to complete our description. If we take the morning tide of April 29th, for instance, we can see that it is generated partly by the direct action of the moon with the declination south *ascending* (a circumstance which is favourable to its development), and partlyby the direct action of the sun with declination north. The evening tide, on the contrary, is connected with the action of the "anti-moon" in the northern hemisphere, and that of the "anti-sun" in the southern. The former, therefore, is a *lunar* tide compounded with a *solar*, and the latter is an *anti-lunar* tide compounded with an *anti-solar*. The positions of the moon at each quarter are likewise noted, and also at apogee and perigee, and thus it is seen how the sun's angle and the moon's distance separately affect the height of each tide. The method is new, and is very successful.

XII.—REPORT ON THE SOLID AND GASEOUS CONSTITUENTS OF THE MALLOW SPA, IN THE COUNTY OF CORK.

By WILLIAM PLUNKETT, Fellow of the Chemical Society, and LANCELOT STUDDERT, LL. D., Ex-Scholar, Trinity College, Dublin.

[Read, June 25, 1877.]

AT the suggestion of the Member for the Borough, Mr. John George M'Carthy, M. P., the authors being deputed by the Royal Irish Academy to analyze this mineral water, repaired for the purpose to Mallow, in August last; and the visit was repeated by Mr. Plunkett in the September following. Near the east end of the town, and north of the Blackwater, and at the base of limestone hills sheltering them from the north and east winds, are some warm wells, two of these being in the field adjoining the Spa House, provided by the lord of the manor, Sir Denham Norreys, Bart. This house contains, in the front room, the spring so long used and celebrated.

It is this principal Spa that the authors were instructed to examine; but they thought fit also to determine the gaseous constituents of one of the outside springs, called the Ladies' Well.

The well in the house, besides, supplies the baths in the adjoining room, and its overflow affords enough to the town for domestic purposes. This well is surrounded by a circular margin of stone; it is three feet deep, and two feet and a-half wide.

A tablet there states that "the baths have been found efficacious in the cure of cutaneous diseases, chronic gout, rheumatism, palsy, and stiff joints; (that) they restore the balance of the circulation, allay nervous irritation, and remove pain. The Mallow Spa (it adds) resembles in its properties the hot wells at Clifton, and has been long used for its efficacy in the cure of scrofulous and consumptive diseases."

Doctor Alexander Knox, in his work on "Irish Watering Places," quotes some physicians of Mallow and Cork, much to the same effect.

The principal well in August last showed a temperature of 70·16° F., or 21·2° C., the atmosphere being at 58·1° F., or 14·5° C. Residents of the place agree that this water is warmest in October. the Ladies' Well in August reached 70·8° F., or 21·6° C.; but it is shallower, and more exposed to the sun's heat than the inside spring.

The surface of both wells is overspread with gas bubbles, breaking, and continuously renewed.

"The gas (writes Dr. Knox) was popularly supposed to be principally carbonic acid; but (he adds) if the analysis of Professor Daubeny, instituted on the spot, be correct, it is composed of—nitrogen, 93·5 parts, and oxygen, 6·5 parts" in the hundred.

Analyzing the gases set free at the water's surface, as the authors did, and to which it would seem that Professor Daubeny confined his examination for gases, and also analyzing the gases contained in a measured portion of the water taken from below its surface, which the authors were careful to do, in addition—these double determinations enabled them to go far towards reconciling the apparently conflicting views reported by Dr. Knox.

Moreover, the composition of the gas, as contained in the water, and also the composition of the gas as set free in the spring, agreed so nearly with the composition as calculated in Bunsen's chapter on "Gases absorbed in Mineral Springs," as to be, in his words, a "valuable confirmation of both analyses."

The authors now beg to explain and state the results they obtained for the gaseous and solid constituents of these Mallow waters; the analyses having been conducted in the Laboratory of the Royal College of Science, by the permission of Professor Galloway.

The free gases and the gases absorbed in the water were both examined. The absorbed gases were boiled out from 700 cub. cent. of the water by the method described in Miller's "Elements of Chemistry," part ii., pp. 55, 56; and the analyses were made by the method adopted by Bunsen, as follows:—The gas was measured in an absorption tube, the necessary corrections for temperature, pressure, &c., being made; a bullet of potassic hydrate was then introduced, and time having been allowed for absorption of carbonic acid, the volume was again determined. The remainder was transferred to an eudiometer, mixed with hydrogen and detonating gas, and exploded. The several readings, reduced to 0° C. and one metre pressure, give the necessary data for calculating the amount of the several constituents.

The following are the results:—

PRINCIPAL SPA.—*Free Gases.*

	Volume.	Pressure.	Temp. C.	Vol. at 0° C. and 1 metre pressure.
Gas employed, ...	121·0	·6462	19·4	73·06
After absorption of CO_2, . .	117·0	·6570	19·2	71·82
Gas transferred to eudiometer, .	191·3	·4314	19·2	77·11
After addition of hydrogen, .	219·2	·4604	19·2	94·29
After explosion with detonating gas,	206·4	·4575	21·6	87·51

Whence we get

	P. C.
Carbonic anhydride, . . .	1·70
Oxygen, ...	2·88
Nitrogen, ...	95·42
	100·00

SAME SPA.—*Absorbed Gases.*

700 cc. of the water yielded 20·6 cc. of gases, which is equal to 29·4 cc. in the Litre.

	Volume.	Pressure.	Temp. C.	Vol. at 0° C. and 1 metre pressure.
Gas employed, ...	132·3	·6719	19·0	83·11
After absorption of CO_2, . .	81·0	·6220	18·8	47·14
Gas transferred to eudiometer, .	135·5	·3932	18·8	49·85
After addition of hydrogen, . .	183·0	·4401	18·6	75·41
After explosion with detonating gas,	156·0	·4129	18·8	60·27

Whence we get

	P. C.
Carbonic anhydride, . . .	43·28
Oxygen, ...	5·75
Nitrogen, ...	50·97
	100·00

An examination was also made of the free and absorbed gases in the outer or Ladies' Well.

The free gases had the following composition :—

	P. C.
Carbonic anhydride, . . .	1·49
Oxygen, ...	2·46
Nitrogen, ...	96·05
	100·00

The absorbed gases were :—

	P. C.
Carbonic anhydride, . . .	32·24
Oxygen, ...	10·12
Nitrogen, ...	57·64
	100·00

The solid constituents of the principal spa were also determined. They were found to be silica, iron, lime, magnesia, soda (with trace of potash), chlorine, sulphuric acid, and carbonic acid. In 1000 cc. were contained:—

	Grammes.
$Si\ O_2$,	·0152
$Fe_2\ O_3$,	·0005
Ca	·0564
Mg,	·0097
Na,	·0063
SO_4,	·0126
Cl,	·0176

Which may be calculated as being thus combined:—

Silica,	·0152
Ferric Oxide,	·0005
Calcic Sulphate,	·0179
Calcic Carbonate,	·1279
Magnesic Carbonate,	·0246
Magnesic Chloride,	·0105
Sodic Chloride,	·0160
	·2126

The following are the readings for temperature of the waters and of the atmosphere, taken at the two visits mentioned:—

PRINCIPAL SPA.

31st August, 1876.

Air,	14°·5 C.
Water,	21 ·2 ,,

29th September, 1876.

Air,	13° ·4 C.
Water,	21 ·5 ,,

LADIES' WELL.

31st August, 1876.

Air,	13° ·5 C.
Water,	21 ·6 ,,

29th September, 1876.

Air,	15° ·0 C.
Water,	21 ·8 ,,

XIII.—On the Gaseous Constituents of the Vartry and Grand Canal Waters. By Archibald N. M'Alpine, B. Sc., Assoc. R. C. Sc. I.; and Chris. Clarke Hutchinson, Royal Exhibitioner, Royal College of Science.

[Read, June 25, 1877.]

Hitherto, in the examination of waters for domestic purposes, the attention of chemists has been almost entirely confined to the solid bodies they contain in solution, scarcely any attention having been paid to the gaseous substances present.

That gases, like oxygen, when present in considerable quantities, have no effect upon the human system appears unlikely. The Right Hon. Lyon Playfair believes that the medicinal properties of the mineral waters of Buxton are due to the nitrogen they contain. Whether these gases have, or have not, any action, we must leave to medical men to decide; but, at all events, it seems desirable that in the waters examined for drinking purposes the oxygen contained in solution should be estimated, as, from the quantity of this gas present in waters, some clue might be afforded to the state or condition of the organic matters they contain.

With these objects in view, we undertook, at the suggestion of Professor Galloway, the examination and estimation of the gaseous constituents in the Vartry and Grand Canal waters which are supplied to Dublin, and the neighbouring townships.

We conducted the examination and analyses in the following manner:—

A measured volume of the water under investigation was taken; the gases in this volume expelled, collected, and measured; their quantities were determined, and the respective quantities of each present were estimated, by the refined method of gas analysis devised by Professor Bunsen.

For the expulsion and collection of the gases we used the apparatus proposed by Reichardt, and described by Fresenius in the "Zeitschrift für analytische Chemie," vol. xi., p. 271.

Some preliminary experiments were made upon the gases thus obtained, to ascertain the quality of the gaseous mixture. After the removal of the carbonic acid, by means of a potash bullet, and of the oxygen by a coke bullet, saturated with pyro-gallate of potash, the measured gas remaining in the eudiometer was exploded with a measured volume of oxygen, and a detonating mixture of hydrogen and oxygen, obtained by the electrolysis of water. No contraction occurred, other than that due to the detonating gas; the potash bullet was again introduced, and on measuring, the volume remained as before; hence, we inferred, since no carbonic acid had been formed, that carbonic oxide and carburetted hydrogen were absent, and that the gaseous mixture consisted only of carbonic acid, oxygen, and nitrogen.

We now proceeded to the quantitative estimation of the respective gaseous constituents.

The total volume of gas given off by the known volume of water was measured in a calibrated eudiometer, and in common with the other readings reduced to the normal temperature and pressure (0° C. and 760 *m.m.s.* bar. pres.)

A portion of this gas was taken, transferred to another eudiometer, and measured. After absorption of the carbonic acid by a potash bullet, the gas was again read off by the kathetometer, the difference between the readings giving the amount of carbonic acid.

Pure hydrogen evolved by electrolysis was then introduced, and the volume then read off, to ascertain the amount of hydrogen added. The spark given by a Rhumkorff's coil was then passed, and after allowing it to cool, the resulting volume of the exploded gases was read off: one-third of the contraction measures the amount of oxygen present.

The residual hydrogen in the gas having been deducted, the remaining volume gives the amount of nitrogen present. From data thus obtained, were calculated the percentage composition, the absolute volumes in cub. cents. of the gases given off by the measured portion of the water employed; and, from this last, the total volume of the mixture contained in one million litres of water.

We now proceed to give the results of some of our analyses of the Vartry and Canal waters. The samples of the Vartry water were taken from the taps in the Chemical Laboratories of the Royal College of Science, Stephen's-green, Dublin, being collected just before use:—

No. I.—*Taken 25th March*, 1877.

Volume used, ... 2·420 litres.
Temperature of water used, . . . 7° C.

	Volume.	Temperature in o° C.	Pressure in m.m.s.	Column of Mercury above that in trough in m.m.s.	Corrected Volume at 0° C. and 760 m.m.s. pres.
Total vol. of gas evolved, .	180·347	9·90	740·5	49·9	156·05
After absorption of CO_2, .	169·296	9·45	751·0	52·8	148·41
Gas used, ...	282·362	11·10	752·0	288·1	162·09
After the admission of H, .	412·130	10·80	752·0	166·0	300·63
After explosion, . . .	255·990	10·80	752·0	300·6	143·12

Percentage Volume Composition.

Carbonic acid,	4·888
Oxygen,	30·806
Nitrogen,	64·300
Total,	99·994

Absolute Volume Composition in Cub. Cents.

Carbonic acid,	1·934
Oxygen,	12·187
Nitrogen,	25·437
Total,	39·558

1,000,000 litres of water contain 16,346 litres of mixed gases.

No. II.—*Taken 18th June*, 1877.

Volume used,	2·420 litres.
Temperature of water,	20·25° C.

Percentage Volume Composition.

Carbonic acid,	4·465
Oxygen,	30·897
Nitrogen,	64·638
Total,	100·000

Absolute Volume Composition in Cub. Cents.

Carbonic acid,	1·662
Oxygen,	11·503
Nitrogen,	24·065
Total,	37·230

1,000,000 litres of water contain 15,384 litres of mixed gases.

Waters from Grand Canal.

No. I.—*Taken at Haroldscross Bridge, 28th March*, 1877.

Volume used,	2·420 litres.
Temperature of water,	8° C.

	Volume.	Temperature in o° C.	Pressure in m.m.s.	Column of Mercury above that in trough in m.m.s.	Corrected Volume at o° C and 760 m.m.s. pres.
Total vol. of gas evolved, .	Not taken	–	–	–	–
Gas used, ...	315·136	11·2	749·9	256·7	192·505
After absorption of CO_2, .	283·370	11·5	750·5	289·0	161·490
After admission of H, . .	364·980	11·9	756·5	205·0	251·300
After explosion, ...	227·120	12·2	756·5	313·5	124·550

Percentage Volume Composition.

Carbonic acid, ...	16·111
Oxygen, ...	21·947
Nitrogen, ...	61·941
Total, . . .	99·999

No. II.—*Taken at Leeson-street Bridge, 11th April,* 1877.

Volume used, ... 2·420 litres.
Temperature of water, . . . 10° C.

	Volume.	Temperature in o° C.	Pressure in m.m.s.	Column of Mercury above that in trough in m.m.s.	Corrected Volume at o° C. and 760 m.m.s. pres.
Total vol. of gas evolved, .	354·320	12·3	756·5	241·8	224·850
Gas used, ...	314·718	12·3	756·5	241·8	199·720
After absorption of CO_2, .	197·400	10·2	760·0	361·2	097·524
After admission of H, . .	323·840	10·3	760·0	244·7	207·745
After explosion, ...	214·860	10·4	759·5	345·0	110·318

Percentage Volume Composition.

Carbonic acid,	51·161
Oxygen,	16·260
Nitrogen,	32·569
Total,	99·990

Absolute Volume Composition in Cub. Cents.

Carbonic acid,	26·918
Oxygen,	8·558
Nitrogen,	17·138
Total,	52·614

1,000,000 litres of water contain 21,741 litres of mixed gases.

No. III.—*Taken at Baggot-street Bridge, 21st June,* 1877.

Water used, ... 2·420 litres.
Temperature of water, ... 21·8° C.

	Volume.	Temperature in 0° C.	Pressure in m.m.s.	Column of Mercury above that in trough in m.m.s.	Corrected Volume at 0° C. and 760 m.m.s. pres.
Total vol. of gas evolved, .	302·80	19·9	756·0	302·8	240·810
Gas used, ...	256·43	19·9	756·0	302·8	137·800
After absorption of CO_2, .	163·10	19·9	756·0	392·4	057·802
After admission of H. . .	318·24	19·7	756·0	240·0	194·850
After explosion, ...	234·00	19·2	750·3	308·8	122·238

Percentage Volume Composition.

Carbonic acid,	57·8334
Oxygen,	17·6567
Nitrogen,	24·5097
Total,	99·9998

Absolute Volume Composition in Cub. Cents.

Carbonic acid, ...	32·588
Oxygen, ...	9·949
Nitrogen, ...	13·812
Total, . . .	56·349

1,000,000 litres of water contain 23,285 litres of mixed gases.

It will be desirable to compare the relative quantities of oxygen and nitrogen obtained in these analyses with the relative proportion of these gases which would be dissolved by a pure water, in contact with air. Bunsen has determined, that in 100 parts of oxygen and nitrogen, dissolved by pure water, the relative proportions are—

Oxygen, ...	34·91
Nitrogen, ...	65·09

Comparing the results of our analyses of the Vartry waters with this determination, we find that in 100 parts of dissolved oxygen and nitrogen the following relative proportions obtain:—

No. I.

Oxygen, ...	32·39
Nitrogen, ...	67·61

No. II.

Oxygen, ...	32·34
Nitrogen, ...	67·66

From this we see that these relative proportions of oxygen and nitrogen pretty closely agree with those which are found in a pure water; but there has been a slight diminution in the proportion of oxygen.

Now, *if* a diminution of oxygen is brought about, in consequence of oxidation of decaying organic matter with which a water comes in contact, then, in the Vartry water, such contamination would seem to have occurred only to a very small extent; and, therefore, on this supposition, it is free from injurious organic constituents.

Making the same comparisons for the Canal waters, we obtain the following:—

No. I.—*From Haroldscross Bridge.*

Oxygen, ...	26·16
Nitrogen, ...	73·84

No. II.—*From Leeson-street Bridge.*

Oxygen, ...	33·368
Nitrogen, ...	66·632

No. III.—*From Baggot-street Bridge.*

Oxygen, ...	41·873
Nitrogen, ...	58·127

These results seem contrary to expectation; for, since in coming further down the canal into the city, the amount of contamination increases, we would naturally expect to find a gradual diminution in the relative quantity of oxygen present. But we really see that the amount of oxygen, relatively to the nitrogen, is increased, the nitrogen undergoing considerable diminution. How this result is to be interpreted we are not as yet prepared to say, further than that our results show us that, as the contamination increases, the proportion of nitrogen *diminishes*, while that of the carbonic acid *increases* by about the same amount.

It may be, that the coefficient of solubility of the nitrogen is altered, owing to the presence of such a large amount of carbonic acid. But upon this point we have found no experimental data.

These investigations were made in the Chemical Laboratories of the Royal College of Science, under the direction of Professor Galloway.

XIV.—On the Volumetric Estimation of Chromium. By Thomas Bayley.

[Read, June 25, 1877.]

The well-known property possessed by the peroxides of Nickel and Cobalt, of decomposing Sodic Hypochlorite with evolution of oxygen, can be made use of for the estimation of Chromium, as follows:—

The Chromium salt is mixed with ·1 or ·2 gram. of Cobalt in solution, and then with excess of Potash or Soda. To this mixture, excess of cold NaClO, free from Chlorate, is added. On warming the solution, the whole of the Chromium is at once oxidised to the state of Chromate, and peroxide of Cobalt (Co_3O_5) is formed at the same time. The solution is then allowed to stand in a warm place for a few hours, in order that the excess of Hypochlorite may be decomposed by the Cobaltic peroxide. Hydrochloric acid is afterwards added until a few drops *only* are in excess; the solution is then boiled until all the Chlorine is expelled. The solution then contains the Cobalt as protochloride, and the Chromium as alkaline Chromate; when cold it is mixed with Potassic Iodide and Hydrochloric acid, and the liberated Iodine is estimated by Sodic Thiosulphate solution. 25 cc of a standard solution of Bichromate of Potassium, equivalent to ·3171 gram. of Iodine, were reduced to Chromous Chloride by Hydrochloric acid and Alcohol, and then estimated by the above method. The following results were obtained:—

Of Iodine.

Theory.	Found.
·3171 gram.	·3212 gram.

In a second experiment:

·3171 ,,	·3171 ,,

The results contained in this Paper were obtained in the Laboratory of the Royal College of Science.

XV.—Notes on the Meteor of Friday the 6th April, 1877. By Professor O'Reilly.

[Read, April 9, 1877.]

This Meteor, seen from many places in the South of Ireland, where it apparently exploded, was also visible from Dublin and other localities still further north. It must consequently have been of more than ordinary size and brilliancy, meriting therefore some notice as a matter of record.

Owing to the peculiar conditions under which such phenomena occur, the impressions and estimates of individual observers naturally differ considerably as regards the colour, the size, and the direction of movement of such a meteor.

The real conditions can therefore be merely approximated by comparing a large number of individual descriptions. In the case, however, of the meteor having been seen to explode at the instant of its apparent passage across some fixed point or line, there remains an element by which its position at the moment can, to a certain extent, be fixed. This advantage I had when observing the explosion, the globe of flame appearing just to touch, by its lower rim, the ridge of the houses on the opposite of the road, as I endeavour to show in the accompanying drawing. Knowing the point where I stood at the time, I have been able to fix the apparent angle of the luminous globe above the horizon, at 15°, using for that purpose a pocket sextant and a level, so as to get a horizontal plane of comparison.

The colour appeared as that of cupric chloride when burning, that is, *bluish green.*

The size of the globe seemed to me to equal that of the setting sun.

The *time* was very nearly three to four minutes past 9 o'clock, P.M., Dublin time.

The *direction* in which seen was about S.W.

The *inclination* of the line of movement appeared to be from west to east, at about 80° from the vertical.

Comparing these observations with others communicated to the Cork newspapers, which I annex, I find the following additional *data*, which agree very fairly, in some respects, with my observations:—

"The Friday night Meteor.

"to the editor of the 'cork examiner.'

"Dear Sir,—I suspect that all your readers have been discussing the splendid meteor which visited us last night. I think it would be worth while if several who observed it compared notes, so as that we may discover what its distance from us was, and, if possible, also its size. I happened to see it from first to last. I must add that I live in the eastern part of the county, exactly in the 8th degree of longitude.' To me the meteor appeared in the heavens exactly about the place of the Polar star. It moved in a south-westerly direction, and traversed an arc of about 60 degrees. It was in view about six seconds. During the last half second it appeared to throw out sparks as if exploding, the colour in the meantime having

become more ruddy. About three minutes after its appearance I heard the explosion. As sound travels fourteen miles a minute, the meteor must have been forty-two miles from me when the first explosion occurred; that is, as I calculate, nearly over the Old Head of Kinsale, but rather south of it, and at a height then of thirty miles. While exploding it must have gone twelve miles farther, and its remains may have fallen among the fishing fleet. The meteor appeared to me to have a diameter about one-tenth the apparent diameter of the moon. Hence its real diameter must have been about 200 feet. I calculate its velocity to have been twenty-five miles a second.

"Hoping you may think my observations worth reading,

"I am yours,

"NO ASTRONOMER."

"THE PHENOMENA OF FRIDAY NIGHT.

"'CORK DAILY HERALD.'

"Our Tralee correspondent wrote on Friday night:—

"'A strange meteoric phenomenon was observed here to-night, at a few minutes past nine. Some persons assert that a ball passed along the heavens, and after a second or two it exploded. Immediately the most minute object was observable by the illumination produced. The light only lasted for a few seconds, and it is positively stated that, after the explosion of the ball, fragments of it fell outside the suburbs, and noise resembling thunder was heard after the explosion.'"

"Our Kinsale correspondent writes:—

"'Those "toilers of the deep" who were at sea fishing on Friday night had a good opportunity of observing the meteor. It resembled very closely the full moon, and carried a trail very much like that of a rocket. It shot through the heavens form north-east to south-west, in which point it disappeared. The brilliancy of the blue light which emanated from it, as it sped along the clear sky, made the smallest object on the earth quite visible, and in a few minutes after its disappearance a deep dull sound like distant thunder was heard in a south-westerly direction, which leaves no doubt that it was the noise which followed.'"

"A correspondent writes to us from Kilrush:—

"'An aerolite (*sic*) of remarkable brilliancy and size illuminated the town after nine o'clock last night, and burst noiselessly. It was for more than thirty seconds in view. It was observed by hundreds who were in the streets.'"

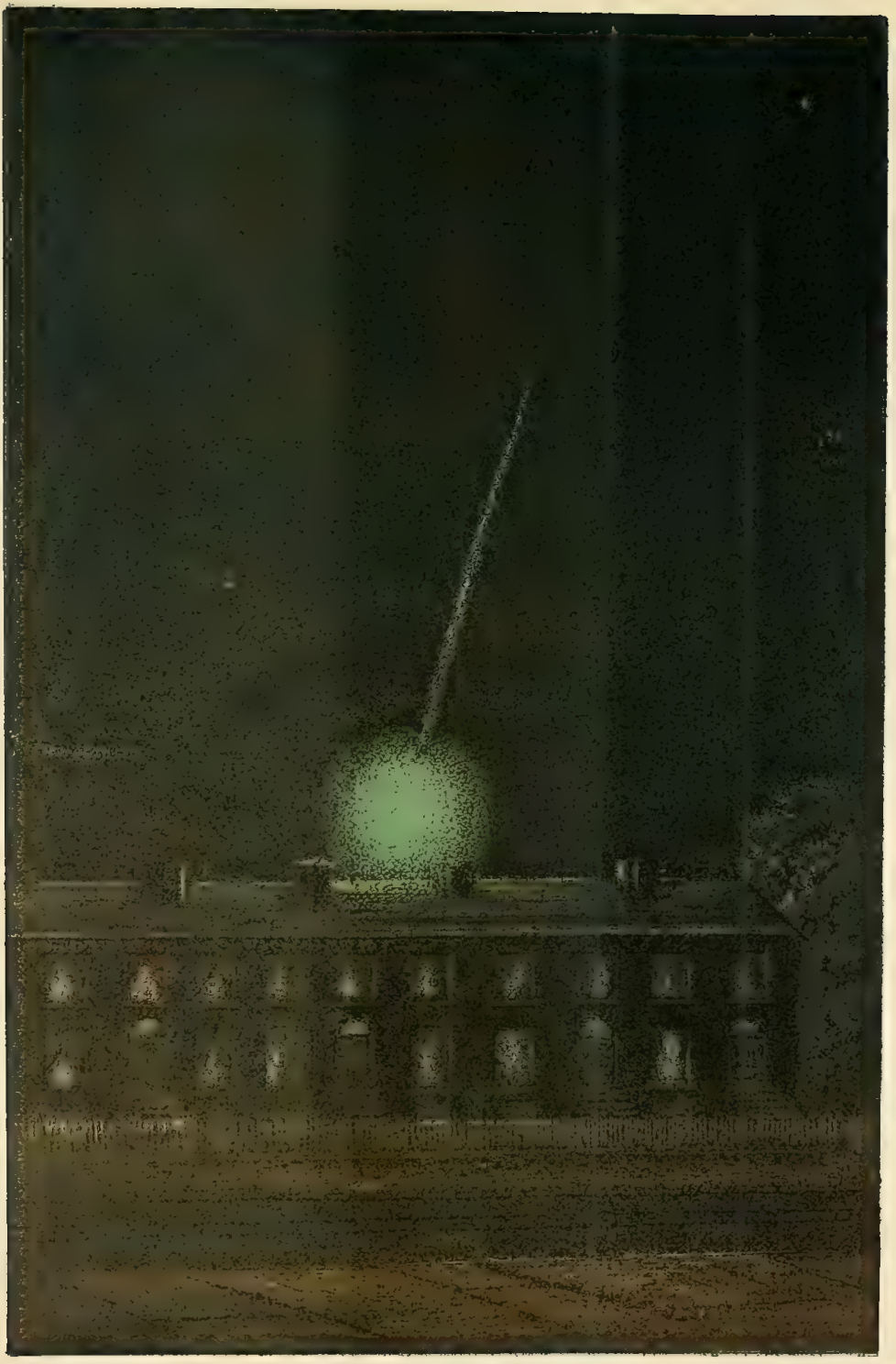
The writer, "No Astronomer," gives the size as about one-tenth the apparent diameter of the moon. Refraction would of course make it appear larger to a spectator situated at Dublin, who saw it at the comparatively low angle of 15°.

The height over Cork which he estimates for the globe, at the moment of the explosion, agrees with that resulting from the 15° altitude which I observed.

The direction of movement which he noted S. W. leads to the conclusion that the plane of movement had a westerly inclination.

The Kinsale correspondent gives the size of the meteor as *that of the full moon* (a sufficiently close approximation to mine); the colour he states as *brilliant blue* (a colour hardly distinguishable from brilliant green at night, by many people).

A correspondent writing from Cork gives the colour as *light blue*, and gives as the interval of time between the explosion and the sound *about two minutes*, the time being about 9 o'clock, P. M.



XVI.—Report on the History of Irish Fossil Mammals. By A. Leith Adams, F. R. S., F. G. S., Professor of Zoology in the Royal College of Science for Ireland.

(Abridgment of the Report.)

[Read, June 10, 1877.]

The following Abstract has been furnished at the request of the Committee of Publication of the Royal Irish Academy, in consequence of the original Report requiring more illustrations than were considered advisable to recommend, on account of the attendant expense.

The extinct and fossil mammals of Ireland have been variously enumerated. Several of the latest writers on the subject include domesticated oxen, sheep, and goats among the feral lost animals,[1] whilst certain mammals are enumerated whose existence appears doubtful when carefully compared with typical examples of the species to which they have been referred.

According to the views apprehended in this Paper, the only extinct mammals hitherto discovered in Ireland are as follows:—

Wild Horse (*Equus caballus*).
Wild Hog (*Sus scrofa*).
Irish Elk (*Cervus megaceros*).
Reindeer (*Cervus tarandus*).
Hairy Elephant (*Elephas primigenius*).
Grisly Bear (*Ursus fossilis, vel U. ferox fossilis*).
Wolf (*Canis lupus*).

Of recent Irish mammals, the only species hitherto found in fossil states are the Alpine Hare (*Lepus variabilis*), and the Fox (*Canis vulpes*), and Red Deer (*Cervus elaphus*).

The so-called fossil Cetacean remains reported to have been discovered in Ireland refer, as far as I can make out, to detached bones, none of which have been determined as belonging to extinct or fossil species.

Again, the asserted discoveries of exuviæ of certain quadrupeds in Irish strata, to wit, Hippopotamus, Ursus spelæus, Ursus maritimus, Ursus arctos, Cervus alces, appear to me to rest altogether on unsatisfactory evidence. On these accounts I conclude that my researches into their histories have not been a work of supererogation; for, although it is demonstrated thereby that the list of Irish fossil mammals is remarkably small as compared with England, and in several respects deficient as compared with Scotland, the objects, as far as they extend, belong to lost mammals, with one exception, also met with in the

[1] Hull, "On the Physical Geology of Ireland" (1878). Scott, *Geological Magazine*, vol. vii.

superficial deposits of the latter country—a circumstance of some importance when the recent and extinct animals are considered in relation to physical geology and their probable route of migration to Ireland after the Glacial Period.

I shall now proceed to briefly indicate the data on which the foregoing determinations are based.

The Wild Horse (*Equus caballus*).

Remains of a small Horse, including many bones, but no teeth, were found in Shandon cave in connexion with the Mammoth, Reindeer, Red Deer, Wolf, Cave Bear (*U. fossilis*, Goldf.), Fox and Hare.[2] Mr. Thompson also refers to teeth from gravel at considerable depths,[3] and many other cases are recorded of the finding of remains in similar deposits. There are also many instances of equine and domesticated animals' remains from caves and prehistoric dwellings, such as crannoges.[4]

The only evidence in connexion with the discovery of remains of *Hippopotamus* in Ireland rests on a single canine tooth said to have been found near Carrickfergus in 1837. I have seen a well executed drawing which is reported to be of this tooth, by the late M. Du Noyer, in the office of the Geological Survey of Ireland. On submitting a copy to Dr. Moore, F. L. S., Naturalist to the Survey, when the discovery was made, he assured me that the above was a true representation of the tooth in question. The specimen, however, is lost, and the circumstances connected with the discovery not being altogether satisfactory, it appears to me prudent to allow the Hippopotamus a place for the present among the doubtful Irish mammals.[5]

The Wild Hog (*Sus scrofa*).

Remains of the Hog are found in caverns, bogs, and crannoges, &c., in connexion with domestic animals, and there are records of its existence in a feral state in Ireland,[6] but I can find no traces of its contemporaneity with the Mammoth and other pleistocene mammals. Nor is there satisfactory evidence of any feral Bos having been indigenous to Ireland.[7] Historians mention wild cattle, but possibly

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[2] Carte, *Journal Royal Dublin Society*, vol. ii., p. 11. Adams, *Trans. Royal Irish Academy*, vol. xxvi., p. 215.

[3] Owen, *British Fossil Mammals*, p. 391.

[4] Bryce, *Report British Association*, 1834, p. 658. Wilde, *Proceedings of the Royal Irish Academy*, vol. i., p. 420.

[5] Dr. Moore makes a mistake in calling it "an Elephant's tooth" in a letter quoted by Professor Hull, *Journal of the Royal Geological Society, Ireland*, vol. iv., p. 61. The tooth is said to have been found by a son of the well-known Mr. Doran, who collected natural objects, and disposed of them to the officers of the Geological Survey of Ireland.—A. L. A.

[6] Wilde, *Proceedings of the Royal Irish Academy*, vol. vii., p. 208. Giraldus Cambrensis, *Toph. Hibernica*, who says the boars were all deformed, and cowards.

[7] Scowler, *Journal of the Geological Society, Dublin*, vol. i., p. 228.

these were only domesticated animals run wild.[8] Remains of *Bos longifrons* are very plentiful in bogs, river, and lake deposits, along with Sheep, Goats, Horse, Red Deer, Dog, and Fox.[9] It has also been discovered in ancient dwellings, such as crannoges, raths, &c.,[10] and many crania showing their frontals battered in by the poll-axe from these situations, and from other prehistoric dwellings, are preserved in the Museum of Science and Art, Dublin, but I have failed in procuring proofs of its existence as a feral species.

The Irish Elk (*Cervus megaceros*).

Enormous quantities of remains of this Deer have been found in sub-turbary deposits, and occasionally in river gravels throughout the island. None of the bones, as far as I have seen, show that either man or beast preyed on the animal. The remarkable incisions frequently observed on its bones from the shell marl are, beyond doubt, as pointed out by Carte, Jukes,[11] and others, the result of friction of opposing surfaces of bones during probable oscillations of the superincumbent bog. This Deer probably existed at the same time with the Cave or Grisly Bear, seeing that remains of the latter have been met with in shell marl under peat of possibly the same age; and there is evidence of its contemporaneity with the Reindeer.[12] The fact that heads of females and hornless heads of Stags are rarely found, whilst cast antlers are not uncommon, may be owing to the absence of the stupendous appendages which would have always greatly interfered with the animal when swimming, as it also assurely placed him at a disadvantage in the forest.

Perhaps, therefore, these accidents occurred at seasons when the sexes were separated, and to all appearances when the horn was in its prime, which would be at the rutting season. A fine head and horns of Reindeer was found by Mr. Moss in lacustrine deposits under bog at Ballybetagh, County Dublin;[13] and quite recently Mr. Williams, Taxidermist, Dame-street, showed me an antler discovered by him in the above situation. In both cases they were associated with, or near to, enormous quantities of remains of *Cervus megaceros*. Taking the explorations made by Messrs. S. & J. Moss, and the two years' explorations lately carried out by Mr. Williams, it is estimated that, in a space not exceeding one hundred yards, considerably over a hundred crania of this Stag have been exhumed.[14]

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[8] Ball, *Proceedings of the Royal Irish Academy*, vol. ii. 541; and Wilde, *Idem*, vol. vii., p. 183.

[9] Du Noyer, *Journal of the Geological Society, Dublin*, vol. i., p. 248; and Ball, vol. i., p. 253.

[10] Wilde, *Proceedings of the Royal Irish Academy*, vol. i., p. 426.

[11] *Journal of the Royal Geological Society of Ireland*, vol. i. p. 152; and vol. x., p. 127.

[12] Oldham, *Journal of the Geological Society, Dublin*, vol. iii., p. 252.

[13] *Ibid.*

[14] Moss, *Proceedings of the Royal Irish Academy*, second series. vol. ii., p. 547.

Notwithstanding reiterated assertions to the contrary by every competent Irish observer, and by Owen in the *British Fossil Mammals*,[15] the error that remains of *C. megaceros* have been met with in peat overlying the shell marl and clays continues to be propagated. It is stated by Dawkins and Sandford in their *Monograph on British Pleistocene Mammals*,[16] published by the Palæontographical Society, that the *Cervus megaceros*, *C. tarandus*, *C. elaphus*, and *Bos longifrons*, have been found associated in peat in Ireland. Now, although remains of the Red Deer and Short-horned Ox are very plentiful in the peat, there is not, as far as I can discover, a single properly authenticated instance of exuviæ of either of the other two Deer having been found in the Irish turbaries overlying the shell marl and clays in which they are embedded.

A descriptive osteology of this Deer appears to me a desideratum, and more especially considering the abundance of its remains, and the excellent states of preservation in which they are met with in Ireland.

The Reindeer (*Cervus tarandus*).

The evidences of the Reindeer in Ireland were first recorded by Oldham;[17] it seems requisite, however, as far as possible, to enumerate the stratagraphical conditions under which the different discoveries were made:—

1. Two almost perfect heads with horns were found in shell marl under bog at Ballyguiry, near Dungarvan, county Waterford.[18]

2. The head and horn referred to in connexion with the Irish Elks' remains from Ballybetagh, county Dublin, were found in a clay overlying granitic boulders, and under peat.

3. A superb head, with mandible and horns, was found under peat at Ashbourne, in the county of Dublin.[19]

4. Several shed antlers, with a fragment of a skull and horn, were dredged from the bed of the Shannon, near Limerick.

5. A skull was found in the mud of Lough Gur, county Limerick.

6. A large number of remains, representing at least thirty-five individuals, were found in Shandon cave, near Dungarvan, associated with bones of the Mammoth, Grisly Bear, Wolf, Fox, Horse, Red Deer, and Hare.[20]

All these specimens are either in the Museum of Trinity College, or in the Museum of Science and Art.

The noteworthy character of the horns of all these finds is the

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[15] Page 464.

[16] Page xiii.

[17] *Journal of the Geological Society, Dublin*, vol. iii., p. 252.

[18] Carte, *Journal of the Geological Society, Dublin*, vol. x., p. 107. Adams, *Transactions of the Royal Irish Academy*, vol. xxvi., p. 210.

[19] Carte, *Journal of the Geological Society, Dublin*, vol. x., p. 103, and Plate viii.

[20] Carte, *Journal of the Royal Dublin Society*, vol. ii., p. 12. Adams, *Transactions of the Royal Irish Academy*, vol. xxvi., p. 217.

uniformity as regards the beam, which is slender and round, as obtains in the English specimens, and the recent Reindeer of Norway, as compared with the flattened antlers of the Siberian stock. The presence of Reindeers' and Horses' bones in the surface as well as the deeper deposits of Shandon cave might indicate that they survived the Mammoth and Bear in Ireland.[21]

Remains of the Red Deer have been found in shell marl and other sub-turbary deposits of Ireland, but in by far the greatest abundance in the peat. Its presence in Shandon cave with the fauna just mentioned, and association with the Irish Elk, make it contemporaneous with all the pleistocene Mammals.[22] I have not seen Irish antlers of the maximum dimensions of the horns from English cave and river deposits.

There is no valid proof whatever that remains of the Elk (*Cervus alces*) have been found in Ireland. The horn referred to by Thompson,[23] and now in his collection at Belfast, is clearly that of a recent Elk.

THE MAMMOTH (*Elephas primigenius*).

The presence of this Elephant in Ireland is confirmed by the following discoveries:—

1. The teeth of a young individual were found in Cavan, in 1715.[24]

2. A rib, possibly of an Elephant, is figured by Smith, who states that it was dug up near Whitechurch, in the county of Waterford.[25]

3. Nearly an entire skeleton of an Elephant, with the antepenultimate molars entire, was discovered in Shandon cave, near Dungarvan, in the county of Waterford, in connexion with remains of Reindeer, Red Deer, Wolf, Fox, *Ursus fossilis*, Horse, and Hare. These remains are now in the Museum of Science and Art, Dublin.[26]

4. There is a nearly entire right humerus, No. 30, 531 of the Palæontological Collection of the British Museum, recorded as having been dredged up in the Bay of Galway. It is covered with Cirripedia belonging to the genus Lepas, and bears every indication of marine origin. The characters of the Mammoth's humerus are well shown in this specimen. The locality indicates the most western point in the European distribution of the species hitherto recorded.

5. I have lately been shown a photograph of portion of a molar of this Elephant by the Rev. Dr. Grainger, D. D., of Browshane, who states that he found it sticking in a marine deposit containing recent shells, near Corncastle, county Antrim. He further informs me that

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[21] Adams' Report on the Exploration of Shandon cave; *Transactions of the Royal Irish Academy*, vol. xxvi., p. 215.

[22] *Transactions of the Royal Irish Academy*, vol. xxvi., p. 224.

[23] *Report of the British Association*, 1840, p. 362.

[24] Molyneux, *Philosophical Transactions*, vol. xxix., p. 367.

[25] Smith, *History of Waterford* [1741], p. 81. Plate 2; figs. 1, 2, and 3.

[26] Carte, *Journal of the Royal Dublin Society*, vol. ii. Plate, x.; p. 11. Adams, *Transactions of the Royal Irish Academy*, vol. xxvi., p. 212.

the other instances referred to by him in his communication to the British Association now turn out to be doubtful.[27] The above are the only properly authenticated instances of the discovery of Mammoths' remains in Ireland (as far as my investigations extend).

Grisly Bear (*Ursus fossilis, sive ferox*).

The Irish ursine remains as determined by Ball, Carte, and others,[28] are stated to belong to the *Ursus maritimus, U. spelæus, U. ferox,* and *U. arctos.*

1. As regards *Ursus maritimus,* the data on which the determination was established comprise a humerus, femur, and fibula, besides portion of the atlas and axis; the two latter, strange to say, display complete ankyloses of their articulations. These bones were found in the mud of Loch Gur, in the county of Limerick, and are at present in the Museum of Science and Art.

In comparing the long bones with similar specimens belonging to the Polar Bear, they appear to me to differ from the latter in precisely the same characters as distinguish the bones of the Brown, the Grisly and the extinct cave Bears from the Polar Bear. These points of distinction as regards the latter have been clearly pointed out by Owen,[29] and refer to the (*a*) stoutness of the bones of the Polar species; (*b*) the size and configuration of the internal condyle of the humerus, (*c*) the position of the deltoid ridge; (*d*) the position of the lesser trochanter of the femur. In all these characters the Loch Gur bones disagree with the Polar, and agree with the Brown, Grisly, and Cave Bears, whose long bones are much alike. From the large dimensions of the specimens in question, they seem to belong in all probability to the *Ursus fossilis* of Goldfuss, now generally supposed to be identical with the recent *Ursus ferox.*

The proximal epiphysis of the *humerus* is wanting. The length of the remainder of the bone is 14½ inches. The breadth of the distal articulation is 3·4 inches; maximum width at the distal extremity 5 inches. Unfortunately, the supinator ridge has been destroyed close to its insertion, and prevents me ascertaining the angle made by it with the shaft. The antero posterior diameter at the middle of the deltoid ridge is 2·2 inches; the *femur* is entire, and 18·8 inches in length; the girth midshaft is 5 inches; breadth of the proximal extremity is 5 inches, and the distal 4 inches; the articular surfaces of the latter are 3·7 inches in breadth; the *fibula* is 13 inches in length, and presents the usual variable characters of that bone.

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[27] *Report of the Belfast Meeting of the British Association*, 1875. "On the Post tertiary Fossils of Ireland." By the Rev. Dr. Grainger, D. D.

[28] Ball, *Proceedings of the Royal Irish Academy*, vol. iv., p. 416. Carte, *Journal of the Geological Society, Dublin*, vol. x., p. 114. Scott, *Geological Magazine*, vol. vii., p. 253. Hull, *Journal of the Royal Geological Society, Ireland*, vol. iv., (new series), p. 51.

[29] *British Fossil Mammals*, p. 94.

2. A superb cranium without the mandible is now in the possession of the Earl of Enniskillen, who has kindly furnished me with the following particulars regarding its discovery. It was given to him by Mr. Young, of Monaghan, who told him that he received it from a navvy, and that the latter found it near Ballinamore, in the county of Leitrim, when digging the Shannon and Erne Canal.

The exact stratagraphical position is therefore wanting, but from the light colour of the specimen as compared with the black colouring of the bones from the mud of Loch Gur, it may be presumed that the skull was found in the shell marl, or else the sub-lacustine clay.

The only teeth remaining are the canines and last molar. The latter is 42 × 22 millimetres, and has the contracted posterior of the Grisly and the *Ursus fossilis* of Goldfuss. The zygomatic arcade is not so broad comparatively, nor are the posterior nasal openings so wide as in *Ursus arctos*. In these two particulars the specimen coincides with crania of the Grisly and *Ursus fossilis*. It differs from *Ursus spelæus* or the gigantic cave Bear in the shape of the last molar and size of the posterior nares, which are apparently narrower in the latter than in any of the foregoing.

The maximum length of the skull is 15 inches, and greatest width 9½ inches. Mr. J. Allen states that, out of crania of eight recent Grisly Bears examined by him, five were 14½, three over 15, and one was 16 inches in length. The maximum breadth of none of these, however, attains to that of the Leitrim skull, the width of the largest being only 8½ inches.[30]

3. Nearly an entire skeleton was found *in situ* in Shandon cave, in conjunction with the exuviæ of the Mammoth, Hare, Reindeer, Red Deer, Wolf, and Fox. The bones are enumerated by Dr. Carte, F.L.S., in his Report on the Shandon remains, and referred by him to *Ursus spelæus* and *Ursus arctos*.[31] The specimens are in the Museum of Science and Art.

The cranium is in fragments, but several molars and the left ramus of a very aged Bear, besides a fragment of a right ramus, evidently of a larger individual, remain. There is a diseased condition of the left ankle-joint, whereby the distal extremity of the fibula and corresponding surface of the tibia show extensive exostosis, which must have greatly impeded the movements of the animal as far as its predaceous habits were concerned; however, the Grisly Bear of North America, like its Brown congener, can subsist entirely on vegetable food. All the teeth of the above are larger than any of *U. arctus* I have seen.

The fragments of the maxillæ show the sockets of the small premolars as in the Leitrim skull, whilst the 4th p. m. is bitubercular, and

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[30] *Geographical Variation among North American Mammals.*

[31] *Journal of the Royal Dublin Society*, vol. ii., p. 12. Plates xi. and xii.

the ultimate has the contour of that of the Grisly and *Ursus fossilis*. The dimensions of the crown of this tooth are 40 × 24 millimetres, and the penultimate molar 24 × 20 millimetres.

The mandible includes the canine much injured sockets of the 1st p. m.; the sockets of 1st and 3rd, and portion of the 4th p. m.; the sockets of 1st and 2nd, and the ultimate molar are entire, but very much worn; it is rounded behind, as in *Ursus fossilis*, the same part being usually more angular in *Ursus arctos* and the gigantic cave Bear (*Ursus spelæus*).

The dimensions of this ramus, compared with that of a very old individual of *Ursus ferox*, show it to have belonged to a larger individual. There are seemingly no other points of distinction in this specimen, but the fragment of the articular extremity of the other ramus shows the thick incurved angular process apparently more pronounced, as in *Ursus fossilis* and *U. ferox*, than in *U. arctos*.

The other bones referred by Carte to *Ursus arctos* are an atlas, 2 cervical, 2 dorsal, and 2 lumbar vertebræ, with fragments of spinous processes and ribs. None of these appear to me to present morphological characters of importance. As regards dimensions, however, they represent a large Bear, as compared with recent species. The atlas, for example, gives the following :—

Height of the arch inferiorly, . . .	1·$\frac{5}{16}$ inches.
Vertebral foramen, ...	1·8 × 1·5 inches.
Anterior articular surface, . . .	1·11 × 1· inches.
Posterior articular surface, . . .	1·3 × 1· inches.

The long bones agree in their characters and dimensions with the usual specimens of *Ursus fossilis*, but the femur is fully an inch and a-half shorter than the Loch Gur specimen, which doubtless belonged to a very large Bear. As compared with the elements of a skeleton of an aged Grisly in the Museum of the Royal College of Surgeons of England, they indicate a much larger animal, the humerus being one and a-half inches, the femur one inch, and the tibia one and a-quarter inches longer.

These ursine remains from Shandon cave seem to me referrible to one species, and are indistinguishable from similar parts of *Ursus fossilis*, and *Ursus ferox*.

4. Two crania now in the Museum of the Philosophical Society of Leeds are stated to have been found seven feet under ground in a cut-away bog at Ballymahon, on the borders of Longford and Westmeath.[32] The teeth and mandibles are wanting in both. The skulls show the sockets of the first and third premolars. The zygomatic arcade is like the others just described, and the posterior nasal openings are also of the same character. The specimens differ considerably

[32] Denny, *Journal of the Geological and Polytechnic Society of Yorkshire*, April, 1864.

in size, and indicate a female and an old male, as surmised from the sagittal ridge and frontal triangle.[33] The larger, although greatly exceeding the dimensions of any cranium of *Ursus ferox* or *Ursus arctos* with which I have compared it, is three-fourths of an inch shorter than the Leitrim skull; at the same time there can be little doubt but that all the three belong to the same species.

5. A cranium without mandible; No. 28,906 of the Palæontological Collection in the British Museum is stated to have been found "seven feet below the surface in alluvial deposits under bog oak trees at Clonbourne, King's County."[34]

A portion of the left zygoma is lost. The two canines and the fourth premolar and first and second true molars are preserved in the left maxilla, and the ultimate grinder in that of the right side. The molars and alveoli show indications of carious disease. The skull may have belonged to an aged female, or a small male. It is an inch and three quarters shorter than the Leitrim specimen, with which, and the Shandon one, it agrees in the cranial characters and the last molar; whilst the fourth p. m. is also biturbercular, thus correlating all their points of distinction.

6. A cranium, in the Museum of Science and Art, Dublin, was discovered "in cutting away a new channel for the Boyne above Leinster Bridge, in the county of Kildare." Other bones are stated to have been found at the same time, but have not, however, been preserved.[35] The skull is dark, and, like the bones from the deposits of Loch Gur, contrasts in that respect with the other skulls from the shell marl and clays. Moreover, this skull is much smaller than any of the foregoing, being two and a-half inches shorter than the Leinster cranium. The coronal ridges are not well developed, and although the sutures are closed, it evidently belonged to a female or adolescent male. The zygomata, incisors, ultimate true molar, together with the first and third of the right maxillæ, are wanting. The alveolus of the first premolar of the right side is completely obliterated, which is not by any means common unless in the gigantic cave Bear, where it is very generally absent.

The fourth premolar and successional molars are present in the right maxilla, and are not much worn. The last molar has the round posterior portion of the crown slightly contracted, with the three cusps on the outer side of the grinding surface, and is much of the same size as in *Ursus fossilis* and *U. ferox*. It is 34 × 20 millimetres. The contour of the zygoma cannot be ascertained, but the posterior nares are wider than usually noticed in *Ursus ferox*. This cranium

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[33] Mr. Denny, from such obvious discrepancies in the cranial ridges, has described them as specific distinctions, whereas they are mere conditions relating to age and sex.

[34] *Catalogue of the Industrial Exhibition of Dublin*, 1853, p. 152.

[35] Wilde, *Proceedings of the Royal Irish Academy*, vol. v., p. 53, *Appendix*, and vol. vii., p. 192; fig. 1.

has been supposed, on account of its small size and dark colour, to have belonged to the *Ursus arctos;* but although smaller by a good deal than the usual cranium of *Ursus fossilis*, it is equal to that of a Grisly Bear, with which it is closely related in having a tricuspidated last molar.

Mr. Busk, F.R.S., referring to several of these crania in his Report on Buxham cave,[36] unhesitatingly places them with *Ursus fossilis sive Ursus ferox fossilis*, and, as far as I have seen, this is the only form represented by the ursine remains hitherto reported from Ireland. The absence of the Brown Bear, or rather of any cogent evidence of the animal either in a fossil state or historically,[37] is noteworthy as compared with the Brown Bear of Scotland and England. But the relationship between *Ursus ferox* and *Ursus arctos* is very close, not only as regards the fossil but also the recent individuals; so much is this the case, that individuals are indistinguishable by external appearances; and as to their dentitions and osteologies, Mr. Busk shows in his very exhaustive account of the Quaternary fauna of Gibraltar,[38] that the ursine remains from Genista cave indicate that they belonged to a Bear "closely related to *Ursus fossilis sive priscus*, or to a form intermediate between it and the *Ursus arctos var. isabellinus*." Indeed no recent carnivore presents more well-marked varieties than the *Ursus arctos*, as differentiated by external colouring, but the isabelline variety of the Himalayas and Turkestan presents a more warty or porcine-like grinding surface of its molars than is ordinarly observed in the species elsewhere. This condition, I have no doubt, from extensive observations of the above variety in its native haunts, is the result of altered conditions of life; inasmuch as the isabelline Bear, unable to capture the agile animals of the Alpine regions it frequents, is driven to subsist almost entirely on roots of plants, and other vegetable food; hence its timidity as compared with the *Ursus ferox*, which still continues to follow the Bison.

How far the wider posterior nares in the Brown Bear, as compared with *Ursus ferox*, and in particular *Ursus spelæus*, may be the result of natural selection, giving a more extended surface for smell, on which the recent Brown Bear depends almost entirely in discovering the presence of his most deadly enemy, and also in supplying a condition favourable for free respiratory action, under the trying circumstances in which the animal is now placed, is a point on which it seems to me one is free to speculate, when we come to consider the severe struggles for existence to which an omnivorous plantigrade like the tardy Bear has been subject to throughout the Tertiary Epoch.

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[36] *Philosophical Transactions*, vol. clxiii., p. 632.

[37] Bede, *obiit* 735, A. D., asserts that the Wolf and Fox were the sole large carnivora of Ireland. St. Donatus, *obiit* 840, A.D., writes "*ursorum rabies nulla est ibi;*" and Sylvester Jerald Barry does not mention the animal.

[38] *Transactions of the Zoological Society, London*, vol. x., p. 65. See also Allen, *Op. cit.*, p. 334.

THE WOLF (*Canis lupus*).

The Wolf is included among the Irish pleistocene Mammals, as shown by the discovery of bones and teeth in Shandon cave along with the Mammoth, Reindeer, Horse, &c.[39] It was only exterminated at the beginning of last century.[40]

Vulpine remains identical with the recent Fox, *C. vulpes*, were found in Shandon cave with the foregoing and the other extinct mammals already enumerated. I found its teeth and bones also in the more superficial deposits, accompanied by bones of Horse, Reindeer, Red Deer, Hare, &c.

ALPINE HARE (*Lepus variabilis*).

A cranium and several bones of a Hare found in Shandon cave, along with vertebræ and molars of the mammoth, show shorter and stouter shafts of the long bones than appear in the fossil Hares from Kent's Hole, and the recent *Lepus timidus*, which is not known to have been indigenous to Ireland. The probability therefore is that, as the same parts of *Lepus variabilis* display similar characters, and the so-called variety *L. Hibernicus* being the Hare of the island, it has appeared to me that the above might belong to the latter.[41] Traces of the teeth of a Rodent of about the dimensions of a Rat were evident on the Mammoth, and other remains from the cave of Shandon, but none of its remains were found.

A comparison of the Irish and Scotch lists of Post-tertiary mammals shows an absence in Ireland of the Elk, Roebuck, Urus, Beaver, Hare, Water Rat, Red Field Vale, Meadow Mouse, Common Shrew, and Mole.

The Bear of Scotland was presumably, and very probably, the *Ursus arctos*, but none of its remains have been preserved; considering, however, its affinities to *Ursus fossilis*, the absence of the Brown Bear from the Irish fauna is not very important. The Wild Cat, Weazel, and Foumart are also absentees.

As compared with England and Wales, there is a marked absence in both Scotland and Ireland of the two species of Rhinoceros, Hippopotamus (?), Bison, Musk Sheep, and ancient Elephant, pouched Marmot Pika, Lemmings, Dormouse, Scandinavian Vole, Champagnol, The Lion, Sabre-toothed Lion, Panther, Lynx, Caffre Cat, Arctic Fox, Spotted Hyæna, Glutton, and gigantic cave Bear.

It is important to observe that all the living and extinct mammals of Ireland, with the exception of the *Ursus fossilis*, have been recorded also from Scotland; that is to say, there is no mammal, recent or lost, in the island which is not also found in Scotland.

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[39] Author, *Transactions of the Royal Irish Academy*, vol. xxvi., p. 227.

[40] The Wolf was exterminated in 1710, and was very plentiful in 1652; Smith's *History of Kerry*, 173; Champion, Lombard, &c., &c.

[41] Adams, *Transactions of the Royal Irish Academy*, vol. xxvi., p. 228.

To the absence of the Lions, Panther, Spotted Hyæna, and gigantic cave Bear may be owing the seeming prevalence of the Irish Elk in Ireland; but at the same time it is important to bear in mind that the quantities of remains of this ruminant have been obtained under conditions clearly indicating that the individuals had been drowned in lakes which, during the Post-glacial Period, must have been extremely plentiful throughout Ireland, whose physical aspect would have been then inimical to such as the Marmot, Lemmings, Pika, Bison, and Urus, which delight in broad pastures and grassy uplands.

But the probability is, that the migration came from Scotland, and that there was a land communication between the two countries at the close of the Glacial Period, by which the greater portion of the mammals that had found their ways to Scotland crossed to Ireland. Irrespective of the soundings between northern Ireland and south-western Scotland, there is evidence of the remains of the Mammoth, Reindeer, Irish Elk, and Horse having been found in similar deposits in Ayrshire, Renfrewshire, Lanarkshire, and bed of the Clyde. The Irish Elk has been found in the Isle of Man, and a jaw and teeth of the Mammoth in the harbour of Holyhead, whilst on the other hand the caves of Glamorganshire have produced nearly all the English Post-glacial mammals not met with in Scotland or Ireland; consequently, if an uninterrupted land communication existed between south-western England and Wales, and Ireland, at the close of the Glacial Period, we should expect to find remains of these characteristic mammals, which is not the case. Again, the animals we do find are, for the most part, vagrant species such as the Horse, Mammoth, Reindeer, Red deer, Bear, Wolf, and Fox,[42] so that the severance took place before the slow travelling Mole Beaver, the forest-haunting Elk and Roebuck had time to arrive. It has been suggested by my friend Professor Hull, F. R. S.,[43] that there may have been a narrow channel between the islands, and that the mammals swam across, or arrived on ice-rafts: but looking over the list of the fauna of Ireland, it seems to me that nothing short of a direct land union will meet the requirements of the case.

Excluding the Cetacea, marine Carnivora, and the Chieroptera, it will be found that out of twenty-eight recent species affecting England and Wales, twenty-six are indigenous to Scotland, and fifteen to Ireland; whereas of thirty-two extinct species hitherto recorded for England and Wales, ten have been found in Scotland, and only seven in Ireland.

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[42] According to Thompson, out of eleven British Amphibians and Reptiles, only five have been found in Ireland, including the Agile Lizard, two Tritons, and two Frogs, and about the same proportion characterises the lower groups, to wit, the air-breathing Mollusks and land Arthropoda.

[43] "Presidental Address," *Journal, Royal Geological Society of Ireland*, 1875, vol. iv., (N. S.), p. 52.

XVII.—On the Formation and Composition of some Complex Oxides of Cobalt and Nickel. By Thomas Bayley, Associate Royal College of Science, Ireland.

[Read, June 25, 1877.]

While preparing standard solutions of nickel and cobalt salts for the purposes of a research on the colorimetric relations and on the colorimetric estimation of those metals, I was endeavouring to use a modification of the method of estimating nickel and cobalt, indicated by Bunsen[1], depending for their determination on the iodine liberated by the higher oxides of these metals in contact with hydrochloric acid, and potassium iodide. The method was as follows:—The solution of the nickel or cobalt salt was made alkaline by soda and then mixed with excess of sodic hypochlorite obtained by the action of cold dilute sodic carbonate on fresh bleaching powder.

After allowing the slightly warm solution of nickel or cobalt to stand some time, so as to ensure complete oxidation, the temperature was raised until brisk effervescence ensued, and the solution allowed to remain at that temperature until the excess of hypochlorite was decomposed. When the evolution of oxygen had ceased, the liquid was boiled for about half an hour. I found that by this process it is easy to destroy all matter, except the oxide, capable of liberating iodine on treatment with potassic iodide and hydrochloric acid. The solution having been cooled, it was mixed with excess of potassic iodide, and then with enough hydrochloric acid to dissolve the suspended oxide. The liberated iodine was then estimated by a standard solution of sodic thiosulphate ($Na_2 S_2 O_3$).

In the first experiments I used a standard solution of nitrate of nickel, and calculated the nickel from the iodine set free according to the following equation:—

$$Ni_2 O_3 + 6HCl = 2Ni Cl_2 + Cl_2 + 3H_2O.$$

The results were not satisfactory, as will be seen from the following Table:—

Nickel used.	Nickel found.
grams.	grams.
·1570	·1437
·1570	·1580
·1570	·1465
·1570	·1568
·1570	·1639
·1570	·1541

[1] Ann. Ch. Pharm. lxxxvi. 265.

Besides these analyses there were several which yielded a far less quantity of nickel. The same method was then applied to cobalt, with this difference, that the solution was boiled only for a few minutes, as I found that length of time sufficient for the decomposition of the last traces of hypochlorite. The amounts of iodine liberated were much greater than would be due to the oxide $Co_2 O_3$, while they agreed perfectly with an oxide $Co_3 O_5$, thus :—

Cobalt used.	Iodine liberated.	Theory of Iodine for Co_3O_5.
grams.	grams.	grams.
·1865	·5338	·5343
·1865	·5380	·5343
·1865	·5328	·5343

I now repeated the experiments with nickel, taking care to boil the liquid only a minute or two. In one or two instances it was not boiled, but the precipitate filtered off and washed. The results were as follows :—

Nickel used.	Iodine liberated.	Theory of Iodine for Ni_3O_5.
grams.	grams.	grams.
·1570	·4428	·4521
·0785	·2263	·2260
·1835	·5318	·5284
·1570	·4490	·4521

With a mixture of ·1863 gram. cobalt, and ·1835 gram. nickel :—

Iodine found.	Theory for Iodine due to $Ni_3 O_5$ & $Co_3 O_5$.
grams.	grams.
1·0532	1·0627

In the last case the oxides were not boiled, but the solution was allowed to stand over the steam bath for a few hours.

With solutions of known quantities of nickel, I now made the following experiments. The solution with the suspended oxide was boiled for some hours.

Nickel used.	Iodine found.	Theory of Iodine. for Ni_3O_4.
grams.	grams.	grams.
·1835	·2009	·2642
·1835	·1812	·2642
·1835	·2321	·2642
.1835	·3310	·2642
·1835	·2830	·2642
·1835	·3765	·2642
·1835	·1069	·2642

In the last experiment the solution was boiled for a few days.

A quantity of cobalt nitrate was now mixed with soda and sodic hypochlorite, and allowed to stand in a warm place until effervescence had ceased. The precipitated oxide of cobalt was then well washed with warm water and dried, till constant, under the air pump, over strong sulphuric acid.

A sample of this oxide was then submitted in succession to various temperatures. The results were as follows:—

	grams.		grams.
Oxide taken, . . .	·9278	(Co_3O_5, $4H_2O$).	
Oxide dried at 100° C, .	·8760	Theory for Co_3O_5, $3H_2O$, .	·8770
,, ,, ,, 138° C, .	·8223	,, ,, Co_3O_5, $2H_2O$, .	·8263
,, ,, ,, 310° C, .	·7548	,, ,, Co_3O_5, H_2O, .	·7756

After this experiment there was an appearance of change on the surface of the oxide.

	grams.		grams.
Oxide after ignition to redness, .	·6840	Theory for Co_3O_4, .	·6798.

Another portion of the same sample:—

	grams.		grams.
Oxide dried at 100° C, .	·4070	(= Co_3O_5, $3H_2O$).	
Oxide after ignition to redness, .	·3125	Theory for Co_3O_4,	·3154.

Another sample prepared in the same way, but left longer over the air pump:

	grams.
Oxide taken dried over H_2SO_4 .	·7083.

The oxide was now heated to low redness in a tube in a current of

dry oxygen, and the water given off collected in a tube filled with calcium chloride. The oxide was afterwards ignited to bright redness in air.

	grams.
Calcium chloride tube, .	65·3250
Calc. chl. tube + water, .	65·4680
	·1430 = OH_2

	grams.
Oxide after ignition in the tube, .	·5493
Oxide after ignition in air, .	·5293

The results of this experiment are compared below with the theory for Co_3O_5, $4H_2O$. For a reason which will be seen further on, I have added the theory for Co_2O_3, $3H_2O$.

Theory for Co_3O_5, $4H_2O$.	grams.	Found. grams.	Error. grams.
$4H_2O$, .	·1549	·1428 .	−·012
Co_3O_5, .	·5534	·5493 .	−·004
Co_3O_4, .	·5190 .	·5293 .	+·013

Percentages.

Co_3O_5, $4H_2O$.		Found.	Co_2O_3, $3H_2O$
OH_2, .	21·86	20·16	24·54
Co_3O_4, .	73·27	74·68	73·05
	95·13	94·84	97·59

Winkelbleck obtained an oxide in the same way as I prepared my samples, only that he boiled his with strong potash before washing it. He dried his oxide over strong sulphuric acid. According to him, the formula is Co_2O_3, $3H_2O$. His results were as follows:—

	Per Cent. (1)	(2)	Per cent. Theory.
2Co, . .	53·83	53·93	53·64
3O, . .	21·62	21·46	21·82
$3H_2O$, . .	24·26	24·61	24·54

The question, which is the true formula of the oxide I obtained, is determined by the amount of iodine liberated by the oxide on treatment with potassic iodide and hydrochloric acid. According to the formula $Co_2 O_3$ 3 H_2O, there should be liberated ·402 gram by ·1865 gram of cobalt; according to the formula Co_3O_5, 4 H_2O, ·5343 grams should be liberated. I found in three experiments ·5338, ·5380, and ·5328.

When the oxide Co_3O_5, 4 H_2O, obtained as described above, is boiled for an hour or two in the solution in which it is precipitated, and the amount of iodine liberated then estimated, the result points to the formation of the oxide $Co_{12}O_{19}$ intermediate between Co_3O_5 and Co_2O_3.

Co. taken.	Theory of I. for Co_3O_5	Theory of I. for Co_2O_3		Found.
gram.	gram.	gram.		gram.
·1865	·5343	·4007	(1)	·453
	Mean.		(2)	·463
	·4676		(3)	·462

	Theory for $Co_{12}O_{19}$ Iod.	Found.
		gram.
·0620	·1566 gram.	·1556

In the last experiment a fresh solution of cobalt, and a fresh solution of potassium bichromate (to standardise the thiosulphate), were used.

A quantity of the oxide of cobalt prepared by precipitating with potash and sodic hypochlorite, and *boiling for some hours*, then washing and drying over sulphuric acid *in vacuo*, was submitted to a current of air at a low red heat, and the water collected and weighed in a calcium chloride tube. The oxide was afterwards ignited to bright redness in air.

	grams.	
Oxide dried over H_2SO_4,	·7455	
Oxide after ignition in tube ($Co_{12}O_{19}$),	·6255	
Oxide after ignition in air (Co_3O_4),	·5975	
Calcium chloride tube + OH_2,	65·5900	
Calcium chloride tube,	65·4645	
	·1255	= OH_2

	Theory for $Co_{12}O_{19}$, 11 H_2O. grams.	Found. grams.
OH_2	·1218	·1255
$Co_{12}O_{19}$	·6236	·6255
Co_3O_4	·5940	·5975

Percentage.

	Theory for $Co_{12}O_{19}$, 11 H_2O	Found.
OH_2	16·34	16·83
$Co_{12}O_{19}$	83·65	83·90

On attempting to prepare Ni_3O_5 in the dry state by precipitating, washing, and drying *in vacuo*, I found that the moist precipitate gave off oxygen as soon as the liquid in which it was precipitated was removed. The moist precipitate was allowed to stand some days, and then left over the air pump for about a week, in order to allow time for this change to be complete. Owing to some interruption, I have as yet had time to prepare only one sample by this means. The results of the analysis agree closely with the formula Ni_8O_{11}, 9 H_2O, one-ninth of the water being lost at 100°C.

	Oxide taken. grams.	Theory of Iodine for Ni_8O_{11}, 9 H_2O. grams.	Found. grams.
Dried over H^2SO_4	·1705	·1607	·1661
,, ,, ,,	·2012	·1896	·1895
,, ,, ,,	·2375	·2238	·2243

	Oxide taken. grams.	Theory of Iodine for Ni_8O_{11}, 9 H_2O. grams.	Found. grams.
Dried at 100°C.	·2080	·2005	·2026

The water in this oxide was determined by igniting the oxide in a platinum boat in a combustion tube, and weighing the water lost by means of a calcium chloride tube.

Oxide taken. grams.	Theory for Ni_8O_{11}, 9 H_2O.	Found. grams.
·8723	·1748 grm. OH_2	·1775
	Per Cent.	
OH_2	20·039	20·34

Per Cent.

	Theory for Ni_8O_{11}, 9 H_2O. grams.		Found. grams.
NiO	74·02	(1)	74·15
		(2)	74·29

Summary.

Under the influence of the hypochlorite solution nickel and cobalt form the oxides Ni_3O_5 and Co_3O_5. On boiling the liquid containing Co_3O_5 it loses oxygen, and passes to the form $Co_{12}O_{19}$, intermediate between Co_2O_3 and Co_3O_5. Under similar circumstances, Ni_3O_5 appears to decompose without forming stable lower oxides, although it is probable from the results that the formation of Ni_2O_3 is a stage in the process. The oxides Co_3O_5 and $Co_{12}O_{19}$ appear to be stable at a low red heat; they are distinguished from Co_3O_4 by a slight difference of colour. Co_3O_5 has the following hydrates :—

Co_3O_5, 4 H_2O (dried over H_2SO_4),
Co_3O_5, 3 H_2O (dried at 100°C),
Co_3O_5, 2 H_2O (dried at 138°C),

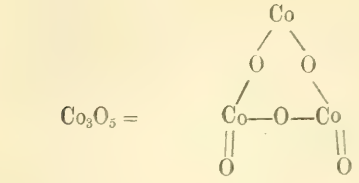
and probably,

Co_3O_5, H_2O (dried at 300°C).

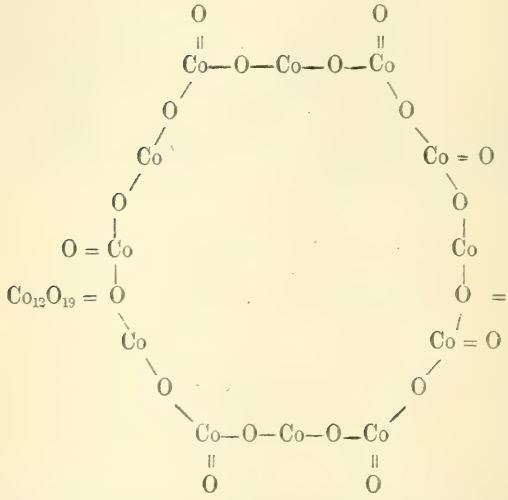
Ni_3O_5 decomposes while still moist when its precipitating liquid is removed by washing. In the one experiment which was made, the resulting dried compound agreed closely with the formula Ni_8O_{11}, 9 H_2O. I have found that, when Co_3O_5, 4 H_2O is treated with cold dilute nitric acid, part is dissolved with evolution of oxygen, and that part remains insoluble. I hope, in a future Paper, to give the results of some similar experiments undertaken for the purpose of determining the proximate constitution of these oxides.

It may at first sight appear that the formula $Co_{12}O_{19}$ is inadmissible on account of its complexity, but as the iodine method clearly shows that the oxide is exactly intermediate between Co_3O_5 and Co_2O_3, and as the formula $Co_{12}O_{19}$ is the simplest formula for such an oxide, it would seem that we must accept it, especially when we consider the tendency of cobalt to form compounds vieing in complexity with many of the products of organic chemistry. It may be that the application of the iodine method to the examination of the oxides of other metals would lead to the acceptance of formulæ more complex than those now admitted. The two oxides of cobalt described in this Paper, and indeed other oxides of cobalt, may be represented graphically by rings some-

what analagous to the well-known benzine ring of the aromatic carbon compounds. Thus:—



$Co_3O_5 =$ $= Co''O,\ 2\ Co^{IV}O_2$



$Co_{12}O_{19} =$ $= 5\,Co'O,\ 7\,Co\ O_2$

This investigation was conducted in the Chemical Laboratory of the Royal College of Science, Ireland.

XVIII.—On the Albuminoid Matters, Alcohol, and Phosphates, in the Burton Ales and in Dublin Porter. By Reginald Lawrence and C. W. Reilly, Associates of the Royal College of Science.

[Read, June 25, 1877.]

The two kinds of malt liquor, Burton Ale and Dublin Porter, are so largely consumed at the present time, that it appeared to us desirable to have the three classes of Dublin porter, as manufactured by Messrs. Arthur Guinness & Son, and the Burton ales, manufactured by the two most noted brewers, Messrs. Bass and Allsopp, examined under the same conditions.

The samples of the Burton ales examined we obtained from Messrs. Falkner, of this city, and we are greatly indebted to the kindness of Messrs. Arthur Guinness & Son for supplying us with the samples of porter we required for our investigation.

We confined our examination to the estimation of the principal constituents:—the phosphoric acid existing in the form of phosphates, the albuminoid matter and alcohol, together with the acetic acid, the total amount of solid matter, and the specific gravities of the different samples.

The phosphoric acid was determined in the ash by a standard solution of acetate of uranium; in the estimation of the albuminous matter, acetic acid, alcohol, and total solids, we followed the plans given by Messrs. Jackson and Wonfor.[1]

We may add that the quantity of albuminous matter was determined by first finding the amount of nitrogen by Will and Varrentrapp's method, and then taking 15·92 parts of nitrogen as equal to 100 parts of albumen.

Our investigations show that some of the principal elements of nutrition are present in larger quantities in the Foreign and ordinary Dublin Double stout than in the Burton ales.

This investigation was carried on in the Laboratory of the College of Science, under the direction of Professor Galloway.

The following are the quantities of the substances we estimated, expressed in grains per gallon:—

[1] Messrs. Jackson and Wonfor "On the Composition of the Dublin Porter."—*Journal of the Royal Dublin Society*, vol. iii., page 163.

	Bass's Ale.	Allsopp's Ale.	Foreign Double Stout.	Double Stout.	Guinness's Single Stout.
Albuminoid Matter,	1st Estimation :— 333·2404 2nd Estimation :— 340·5217 Mean = 336·8810	327·1731 316·7365 321·9548	574·0000 549·6250 561·8125	435·303 422·112 428·708	298·996 316·584 307·790
Acetic Acid, . . .	1st Estimation :— 95·9280 2nd Estimation :— 96·1310 Mean = 96·0295	168·210 167·90 167·05	261·786 255·7058 258·7409	139·300 147·000 143·150	160·580 160·090 160·335
Alcohol, ...	4383·4000 4365·9000 4374·6509	4478·5125 4443·8625 4461·1875	5128·2000	4643·100	3534·3000
P_2O_5, ...	19·425	18·375	123·110	111·088	85·600 79·829 82·715
Total Solids, . .	4884	3110	4374	5068	3838·5
Specific Gravities,	1·0138	1·0144	1·01157	——	1·12438

XIX.—COMPUTATION OF TIDES AT FLEETWOOD.—RESULTS OF THEORY AND OBSERVATION.

By JAMES PEARSON, M. A., Ex-Scholar (15th Wrangler), Trinity College, Cambridge.

[Read, November 12, 1877.]

IN resuming the consideration of the subject of the tides, it is not my intention to enter at any greater length into the theory which has produced results so closely in accordance with observation: it is sufficient for me to make some remarks on the principal cause of such discrepancies as are found to arise where tables have been used which are based upon that theory—and amongst these disturbing influences, the pressure of the atmosphere ranks foremost. A very simple process may be employed to establish this. It is found that, in the same month, but in different years, the same, or nearly the same, constituents have to be employed in computing a tide; and as like causes produce like effects in nature, the resulting tide ought to be the same in both cases. But it is not so, and the variation is found to depend on the height of the mercury in the barometer, or, more correctly, on the magnitude and direction of the gradients indicated in the weather reports issued in the newspapers. Another disturbing element is that which depends on the suddenness with which the pressure shifts its direction. Thus, a south-east wind rapidly changing into a south-west wind causes an unusual elevation of the level of the Irish Sea. Two examples may serve by way of illustration. In the first case there are exhibited two tides which have very nearly the same constituents, and which, in consequence of the atmospheric conditions being the same, give results both agreeing with observation. The heights are given in feet and inches.

CASE I.

	1876, Sept. 3, Morning Tide, Anti-lunar and Solar.		1877, Aug. 23, Morning Tide, Anti-lunar and Solar.	
	d. h. m.	ft. in.	d. h. m.	ft. in.
Moon's Transit, B, .	1 10 39	25 5	21 10 35	25 4
Corr. for Anti-lunar, .		+ 1		+ 1
Moon's Hor. Parallax,	54′ 45″	− 7	54′ 3″	− 11
Anti-lunar Declination,	18° 12′ N. des.	− 7	20° 41′ N. des.	− 10
Solar Declination, .	8° N.	+ 4	12° N.	+ 4
	24 8 obs.	24 8	24 0 obs.	24 0
	Bar. 29 9. No wind.		Bar. 29·8. No wind.	

Case II.

	1876, Sept. 10, Morning Tide, Lunar and Anti-solar.		1877, Aug. 21, Morning Tide, Lunar and Anti-solar.	
	d. h. m.	ft. in.	d. h. m.	ft. in.
Moon's Transit B, .	8 3 30	23 2	29 3 50	22 8
Corr. for Lunar, . .		+ 5		+ 5
Moon's Hor. Parallax,	57′ 53″ +	+ 7	55 50	− 3
Lunar Declination, .	20° 0′ N. asc.	− 4	19° 23′ N. asc.	− 2
Anti-solar Declination,	5° S.	+ 5	9° S.	+ 4
	24 3 obs.	24 3	23 7 obs.	22 11
	Bar. 29·7. No wind.		Bar. 29·6. Wind N.W., strong.	

It is to be observed that, in Case II., although the tide of September 10 has almost all its constituents more favourable to its development than those of August 31, still, in consequence of the atmospheric conditions, a higher tide results in the former case than in the latter.

In the computation of tides, the first thing which is of importance is, that we assign to each tide its proper classification. The transit which is to be employed, as a sort of standard transit from which tides are to be calculated, is the transit next but two preceding that transit which is nearest to the time of high water of the tide considered. This transit is, in fact, the transit B of Sir John Lubbock's Tables. The rule for determining the classification for the tides of the Irish Sea is as follows :—"Lower transits B are followed by lunar tides, and upper transits B by Anti-lunar tides. All transits B which take place between $23\frac{1}{3}$ hours, and $11\frac{1}{3}$ hours (apparent Greenwich time), give *morning* tides; and all between $11\frac{1}{3}$ hours, and $23\frac{1}{3}$ hours (apparent Greenwich time), give *evening* tides. All transits B, after 6 hours, and before 18 hours, are connected with solar tides; and all transits B, after 18 hours, and before 6 hours, with anti-solar tides."

A tabulated comparison of the results of theory and observation is appended, with remarks on the atmospheric conditions in explanation of such discrepancies as are found to occur in them.

TABULATED RESULTS.

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
August 8	M.	26·7	25·10	30·1, S. W.
	E.	25·2	24·5	
9	M.	26·5	25·10	30·1, W.
	E.	25·7	24·7	
10	M.	26·2	25·5	30·1, W. N. W.
	E.	23·11	23·7	
11	M.	25·4	24·9	30·3, E. S. E.
	E.	23·3	23·3	
12	M.	24·1	23·9	30·2, E. S E.
	E.	22·5	22·4	
13	M.	23·0	22·10	30·0, E. S. E.
	E.	21·1	21·6	
14	M.	21·5	21·7	30·0, W.
	E.	20·3	20·5	
15	M.	20·11	21·1	30·0, N. W.
	E.	21·0	21·0	
16	M.	21·8	21·9	30·0, E.
	E.	22·6	22·6	
17	M.	23·4	23·3	30·0, E. S. E.
	E.	24·10	24·10	
18	M.	25·6	25·4	29·9, E.
	E.	26·8	26·7	
19	M.	26·10	26·7	29·9, E. S. E.
	E.	28·2	28·2	
20	M.	28·0	27·9	29·8, N. E.
	E.	—	—	
21	M.	29·2	29·0	29·9, E. S. E.
	E.	28·3	27·9	
22	M.	29·1	28·9	29·9, W. N. W.
	E.	27·9	27·8	
23	M.	28·5	28·4	29·8, W. N. W.
	E.	26·10	26·9	
24	M.	26·9	26·11	29·8, W. N. W.
	E.	25·3	25·8	
25	M.	24·9	24·7	30·0, N. N. E.
	E.	23·5	23·5	
26	M.	22·10	23·2	30·0, S. W.
	E.	21·4	22·6	Strong wind, S. W. gale.
27	M.	20·9	21·6	29·1, W.
	E.	19·9	19·9	
28	M.	19·1	18·11	29·8, S. S. W.
	E.	18·9	19·4	Wind high.
29	M.	18·5	19·9	29·5, W.
	E.	19·1	19·4	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
Aug. 30	M.	18·10	19·3	29·6, W. S. W.
	E.	20·2	22·9	Wind high, S. ; bar. 29·2.
31	M.	20·6	21·4	29·0, W. S. W.
	E.	21·9	22·6	
Sept. 1	M.	21·11	21·9	29·6, N. W.
	E.	23·10	24·1	
2	M.	23·5	23·4	29·8, N. N. E.
	E.	25·2	25·5	
3	M.	24·8	24·8	29·9, W. N. W.
	E.	26·3	26·3	
4	M.	25·9	26·2	29·5, E.
	E.	27·5	27·4	
5	M.	—	—	29·4, S.
	E.	26·6	26·6	
6	M.	28·0	28·0	29·4, S. W.
	E.	26·10	26·10	
7	M.	27·11	27·9	29·5, S.W.
	E.	26·4	26·4	
8	M.	27·2	26·10	29·6, W. N. W.
	E.	25·4	25·1	
9	M.	25·9	26·4	29·7, W.
	E.	24·3	24·3	
10	M.	24·3	24·3	29·7, W. N. W.
	E.	22·9	23·11	
11	M.	22·6	22·10	29·7, W. N. W.
	E.	21·2	21·7	
12	M.	20·8	20·7	29·8, N. W.
	E.	20·0	20·4	
13	M.	20·2	20·4	29·8, N. W.
	E.	20·9	20·11	
14	M.	21·5	21·6	29·8, W.
	E.	22·10	22·10	
15	M.	23·8	23·9	29·8, W.
	E.	25·4	25·4	
16	M.	25·8	25·5	29·7, S. E.
	E.	27·0	27·0	
17	M.	27·2	27·1	29·6, S.
	E.	28·6	28·7	
18	M.	27·11	27·9	29·7, S. W.
	E.	29·7	28·6	Bar. rising.
19	M.	—	—	30·0, W.
	E.	28·3	27·9	Bar. 30·1.
20	M.	28·6	28·1	Bar. 30·1, W.
	E.	27·7	27·3	
Sept. 21	M.	27·8	27·7	30·2, S. E.
	E.	26·6	26·5	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
Sept. 22	M.	26·3	26·4	30·0, S. E.
	E.	25·3	25·3	
23	M.	24·4	24·5	29·8, S. E.
	E.	23·8	24·0	
24	M.	22·4	22·6	Bar. falling.
	E.	21·8	22·10	Bar. 29·9, S. E.
25	M.	20·5	21·3	29·5, S. W.
	E.	19·8	19·9	
26	M.	18·7	18·7	29·8, S.
	E.	18·6	18·7	
27	M.	17·6	17·6	29·6, W.
	E.	18·8	18·8	
28	M.	18·7	18·8	29·6, E.
	E.	20·2	20·3	
29	M.	20·4	20·5	29·4, W.
	E.	21·10	22·0	
30	M.	21·10	21·9	29·6, N. E.
	E.	24·9	23·5	Gale N. N. E.
Oct. 1	M.	23·8	23·5	29·6, N. E.
	E.	25·5	25·1	Bar. rising.
2	M.	24·11	24·5	30·1, E.
	E.	26·9	26·4	
3	M.	25·11	25·11	29·8, E. S. E.
	E.	27·9	27·9	
4	M.	27·3	27·2	29·7, S. E.
	E.	28·6	28·4	
5	M.	—	—	
	E.	27·1	27·4	29·8, E. S. E.
6	M.	28·2	28·1	29·8, S. E.
	E.	27·0	27·2	
7	M.	27·3	27·6	29·8, S. E.
	E.	26·1	26·6	
8	M.	25·10	26·2	29·9, S
	E.	24·7	24·11	
9	M.	24·3	24·7	Bar. fallen.
	E.	22·11	24·4	Bar. 29·4, S. E.
10	M.	22·4	23·5	29·4, S. W.
	E.	21·3	23·1	
11	M.	20·6	21·4	W. gales.
	E.	20·7	23·3	29·1, S.
12	M.	21·0	21·4	29·5, S.
	E.	21·8	22·6	
13	M.	22·4	22·11	29·6, S. W.
	E.	23·9	24·7	
14	M.	24·3	24·7	29·5, S.
	E.	25·8	26·3	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
Oct. 15	M.	26·0	25·10	29·7, S.
	E.	27·0	27·2	
16	M.	27·0	27·5	29·6, S. E.
	E.	28·3	28·3	
17	M.	27·8	27·8	29·6, S. E.
	E.	28·3	28·5	
18	M.	27·9	27·9	29·6, S. E.
	E.	27·10	27·9	
19	M.	—	—	
	E.	27·1	26·10	Bar. 29·8, S.
20	M.	26·6	26·1	Bar. 30. 0, S. E.
	E.	25·10	25·9	
21	M.	25·2	25·0	30·1, N. E.
	E.	24·10	24·2	
22	M.	23·7	23·4	30·2.
	E.	23·3	22·11	
23	M.	21·7	21·6	
	E.	21·9	21·9	
24	M.	20·2	20·2	30·1, S. E.
	E.	20·3	20·6	
25	M.	18·7	18·7	30·2, S. E.
	E.	19·3	19·4	
26	M.	17·7	17·6	30·3, S. E.
	E.	19·3	19·2	
27	M.	18·8	18·5	30·3, S. E.
	E.	20·5	20·3	
28	M.	20·1	19·10	Bar. rising.
	E.	22·0	21·7	Bar. 30·3, S. E.
29	M.	21·10	22·0	Settled.
	E.	23·9	23·5	30·3, S. W.
30	M.	23·6	23·6	30·2, N. W.
	E.	25·7	25·2	
31	M.	25·1	24·5	Bar. 30·3, W.
	E.	26·11	26·0	Bar. 30·4
Nov. 1	M.	25·11	25·7	Bar. 30·4, N. E.
	E.	27·5	27·0	
2	M.	26·6	26·6	30·3, N. W.
	E.	27·10	27·8	
3	M.	27·1	27·3	30·2, S. W.
	E.	—	—	
4	M.	27·7	27·5	30·3, W. N. W.
	E.	26·8	26·7	
5	M.	26·8	26·5	30·3, W.
	E.	25·9	25·11	
6	M.	25·5	25·5	30·3, W.
	E.	24·6	24·6	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft in.	
Nov. 7	M.	23·11	23·8	Wind W., slight.
	E.	23·3	23·4	30·3, N. E.
8	M.	22·5	22·0	Bar. 30·2, S. E.
	E.	22·0	22·2	
9	M.	21·1	20·11	30·1, N. E.
	E.	21·6	21·8	
10	M.	21·3	21·0	Frost.
	E.	22·3	22·4	30·2, N. E.
11	M.	22·5	23·0	Bar. fallen.
	E.	23·4	23·9	29·9, S. E.
12	M.	23·6	23·0	
	E.	24·9	24·6	29·7, E.
13	M.	24·10	24·8	29·3, E.
	E.	25·7	25·3	
14	M.	25·7	25·8	29·6, E.
	E.	26·3	27·3	Bar. fallen, S. S. W.
15	M.	25·10	26·6	29·4, S. E.
	E.	26·3	26·7	
16	M.	26·1	26·4	29·3, E. N. E.
	E.	26·2	26·10	S. W.
17	M.	26·2	26·8	29·8, S.
	E.	—	—	
18	M.	25·7	25·7	29·8, S.
	E.	25·8	26·0	
19	M.	24·9	25·3	Bar. 29·7, S.
	E.	24·7	25·6	Gradients.
20	M.	23·4	24·5	Southerly.
	E.	23·4	24·0	29·7, S. W.
21	M.	22·3	22·5	
	E.	22·6	23·0	Bar. 29·9, W.
22	M.	21·0	21·4	30·1, S. E.
	E.	21·5	22·3	S.
23	M.	19·9	20·3	30·1, S. E.
	E.	20·8	21·3	
24	M.	19·3	19·3	29·8, S. E.
	E.	20·6	20·6	
25	M.	19·0	18·11	29·6, S. E.
	E.	21·0	21·2	
26	M.	20·0	20·2	29·5, S. E.
	E.	22·0	22·3	
27	M.	21·2	21·5	29·4, S. E.
	E.	23·2	22·11	Wind E., slight.
28	M.	22·7	22·8	29·3, N.
	E.	24·6	24·6	
29	M.	24·3	24·5	29·4, W. S. W.
	E.	25·10	25·10	
30	M.	25·7	25·8	29·5, S.
	E.	26·7	26·6	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
Dec. 1	M.	26·10	26·11	Bar. fallen.
	E.	27·5	28·5	Bar. 29·2, S. E.
2	M.	27·5	27·6	
	E.	27·10	26·11	Gale N. E. ; bar. 29·0.
3	M.	—	—	
	E.	27·8	28·6	Bar. fallen ; wind S. W.
4	M.	27·8	28·5	Bar. 28·9.
	E.	26·11	28·5	Stormy.
5	M.	26·6	27·6	Bar. 28·5.
	E.	26·2	27·7	
6	M.	25·2	27·6	Gale S. W.
	E.	25·2	27·0	Bar. 28·9.
7	M.	24·3	25·0	Unsettled.
	E.	24·0	25·3	Stormy.
8	M.	22·11	23·6	29·6, N. W.
	E.	22·11	24·2	
9	M.	22·0	22·3	30·0, W.
	E.	22·9	23·6	
10	M.	22·7	22·7	30·1, S. W.
	E.	23·1	23·7	
11	M.	22·10	23·1	30·0, S.
	E.	23·6	23·8	
12	M.	23·4	24·7	29·6, W. S. W.
	E.	23·11	24·0	
13	M.	24·1	24·1	29·6, S.
	E.	24·3	24·9	Bar. fallen.
14	M.	24·8	25·1	29·7, S.
	E.	24·8	24·5	
15	M.	25·1	25·1	29·8, S.
	E.	24·8	24·8	
16	M.	25·4	25·4	29·7, S.
	E.	24·9	24·7	
17	M.	—	—	
	E.	25·5	25·7	29·6, S.
18	M.	24·6	24·2	29·5, S. E.
	E.	25·4	25·2	
19	M.	23·10	23·10	29·1, S.
	E.	24·10	25·0	
20	M.	23·3	23·3	
	E.	24·4	25·0	Bar. fallen, 28·9.
21	M.	22·8	22·6	Bar. steady.
	E.	23·9	24·3	Gale W.
22	M.	22·3	22·5	28·9, W.
	E.	23·3	23·3	
23	M.	21·7	21·4	29·1, S.
	E.	22·8	22·7	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1876.		ft. in.	ft. in.	
Dec. 24	M.	21·0	20·2	Wind E.; frost.
	E.	22·1	21·3	29·4, S. E.
25	M.	20·6	19·5	29·6, N. E.
	E.	21·10	20·10	,, ,,
26	M.	20·9	19·8	30·1, E.
	E.	22·4	21·5	
27	M.	21·8	23·1	Bar. falling; gale.
	E.	23·1	23·11	S. W.; 29·4.
28	M.	23·0	23·4	29·4, S.
	E.	24·5	24·4	
29	M.	24·9	24·7	29·5, S.
	E.	25·10	27·0	Bar. falling.
30	M.	25·10	26·9	,,
	E.	26·11	27·7	Bar. 29·0, S.
31	M.	27·5	29·6	,, 29·0, S. W.
	E.	27·10	29·0	Bar. falling; gale, S. W.
1877.				
Jan. 1	M.	—	—	
	E.	28·4	29·7	28·8, S.
2	M.	28·3	27·8	Wind W.; Bar. rising, frost.
	E.	28·5	28·8	
3	M.	27·10	27·3	Gale, S. E.
	E.	27·11	27·6	,, ,,
4	M.	27·1	27·0	
	E.	27·0	28·9	Bar. falling; wind S. W.
5	M.	25·10	26·6	Bar. 29·0; S. W.
	E.	25·10	27·0	,, ,,
6	M.	24·4	25·0	,, ,,
	E.	24·3	25·5	Bar. 28·8; stormy.
7	M.	22·9	24·9	,, ,, ,,
	E.	22·6	25·0	High winds, S.
8	M.	21·10	23·1	Bar. 29·1; storm, S. W.
	E.	21·5	22·8	,, ,, ,,
9	M.	21·4	22·0	29·4, S. W.
	E.	21·1	21·9	
10	M.	21·5	21·6	29·9, S. E.
	E.	21·4	21·6	
11	M.	22·2	22·2	29·9, N. E.
	E.	22·0	22·2	Settled and cold.
12	M.	23·1	23·3	29·0, E.
	E.	22·9	22·6	
13	M.	23·11	24·1	Bar. falling.
	E.	23·4	24·0	Wind S.
14	M.	24·8	25·4	Signal flying; Bar. 29·0.
	E.	24·0	25·1	High wind.
15	M.	25·6	25·4	29·8, N. W.
	E.	—	—	

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1877.		ft. in.	ft. in.	
Jan. 16	M.	24·10	24·11	29·9, S.
	E.	26·1	26·2	
17	M.	25·0	25·1	29·7, S.
	E.	26·1	26·1	
18	M.	24·8	24·9	Bar. falling fast.
	E.	25·9	27·0	29·5, S. W.
19	M.	24·4	24·8	Unsettled.
	E.	25·6	27·0	Gale, S. W.
20	M.	23·10	23·4	Sudden rise of Bar.
	E.	25·0	24·10	30·1, S.
21	M.	23·2	22·11	Bar. 30·3.
	E.	24·3	24·1	Wind W.
22	M.	22·2	21·10	Bar. 30·4, S.
	E.	23·2	22·7	,, ,,
23	M.	21·3	21·5	30·4, S. E.
	E.	21·10	22·1	Bar. falling.
24	M.	20·7	20·11	30·0, S.
	E.	21·1	21·0	,,
25	M.	20·7	21·5	Gale, W.
	E.	21·7	21·9	30·0, S.
26	M.	21·9	20·10	Gale, W.; Bar. 30·0.
	E.	22·10	22·7	,,
27	M.	23·4	24·2	Wind S.; Bar. falling.
	E.	24·7	24·3	Sudden rise, 30·0.
28	M.	25·4	27·6	Gale, W.; Bar. falling.
	E.	26·4	27·8	29·8, S. W.
29	M.	27·5	27·6	Wind W.; Bar. rising.
	E.	27·10	29·0	Gale, S. W.; 29·9.
30	M.	28·9	31·0	Hurricane, S.W.; Bar. 29·0.
	E.	—	—	
31	M.	28·9	28·2	Bar. sudden rise to 30·0;
	E.	29·5	29·6	[N. W.
Feb. 1	M.	28·9	29·4	Sudden fall of Bar.
	E.	29·1	29·5	29·8, S. W.
2	M.	27·9	28·0	29·7, S.
	E.	28·0	28·11	Further fall.
3	M.	26·8	27·4	Wind S. W.
	E.	26·5	28·5	29·8, S. W.
4	M.	24·9	25·8	Gale, W. N. W.
	E.	24·2	24·6	29·9, W.
5	M.	23·0	23·3	30·1, W.
	E.	22·2	23·3	
6	M.	21·0	21·0	30·0, S.
	E.	20·2	21·5	Bar. falling.
7	M.	19·9	20·3	Wind high.
	E.	19·3	19·5	30·0, W.

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1877.		ft. in.	ft. in.	
Feb. 8	M.	19·8	19·6	30·1, W.
	E.	19·8	20·0	
9	M.	20·7	20·10	30·1, S. W.
	E.	20·6	21·6	Bar. falling; wind S.W.
10	M.	21·9	22·6	Wind high.
	E.	21·10	22·2	29·8, S. W.
11	M.	23·6	24·9	Gale, S. W.
	E.	22·9	23·3	Bar. still falling.
12	M.	24·7	26·7	
	E.	23·10	24·6	29·6, S. W.
13	M.	25·7	25·11	29·6, W.
	E.	25·0	25·0	
14	M.	26·7	26·11	29·7, S.
	E.	—	—	
15	M.	25·8	25·11	29·8, S.
	E.	27·3	27·5	
16	M.	25·10	26·1	29·6, S.
	E.	27·3	27·4	
17	M.	25·7	25·8	29·8, W.
	E.	26·9	26·0	Wind W., strong.
18	M.	25·0	25·0	Bar. 30·0.
	E.	25·10	25·7	,, 29·7.
19	M.	24·1	24·5	Wind N. W.
	E.	24·8	24·11	29·9, W.
20	M.	22·11	25·6	Gale N. W.; Bar. 29·4.
	E.	23·4	25·6	,, ,,
21	M.	21·6	24·0	Stormy; Bar. rising.
	E.	21·10	20·4	Wind N. E.; Bar. 30·0.
22	M.	20·1	19·6	Wind N. E.; Bar. 30·2.
	E.	20·5	20·8	,, N. W.
23	M.	19·6	17·8	Wind N.; cold.
	E.	20·6	20·3	30·0, N. W.
24	M.	20·10	21·2	High wind, W. N. W.
	E.	22·0	22·6	Bar. falling.
25	M.	23·3	24·6	Gale, N. W.
	E.	24·5	24·7	Bar. 29·2.
26	M.	25·9	25·6	Wind N.
	E.	26·3	26·0	Frost.
27	M.	27·8	27·8	29·8, N. W.
	E.	27·11	27·7	,,
28	M.	29·2	28·8	Hard frost; wind N.
	E.	28·9	28·3	Bar. 30·1.
March 1	M.	—	—	
	E.	29·10	29·8	Wind S.; Bar. falling slowly.
2	M.	29·0	28·11	
	E.	29·9	29·8	30·1, S.

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1877.		ft. in.	ft. in.	
March 3	M.	28·0	28·0	30·1, S. W.
	E.	28·4	28·7	29·9, S.
4	M.	26·6	26·6	29·9, S.
	E.	26·3	26·4	29·9, N. W.
5	M.	24·8	24·6	
	E.	23·10	23·8	29·9, N. W.
6	M.	22·7	22·1	30·0, N. W.
	E.	21·6	21·8	Bar. falling; wind N. W.
7	M.	20·7	20·8	29·6, S.
	E.	18·11	17·7	Gale, N.; Bar. 30·0.
8	M.	18·5	17·0	Wind N., ,,
	E.	17·4	16·6	,, ,,
9	M.	18·5	18·0	,, ,,
	E.	18·2	18·0	30·1, E.
10	M.	19·8	19·6	30·1, S.
	E.	19·6	20·0	30·1, S. W.
11	M.	21·5	21·6	30·1, S.
	E.	21·3	21·3	
12	M.	23·2	24·2	30·0, S.W.; fall of $\frac{1}{2}$ inch.
	E.	22·9	23·6	Strong gale.
13	M.	24·8	24·9	Rising; wind N. N. W.
	E.	24·2	24·6	Gale, N. W.
14	M.	26·0	26·4	,, 29·7.
	E.	25·3	25·0	,,
15	M.	27·2	27·2	29·6, W.
	E.	26·4	27·0	Gale, W.
16	M.	28·1	27·7	Wind N.N.W., 29·0; Bar. rising.
	E.	—	—	
17	M.	26·10	26·2	N. N. W., 29·5.
	E.	28·1	27·3	N.
18	M.	26·6	26·6	
	E.	27·3	27·1	
19	M.	25·9	25·6	
	E.	26·3	26·0	
20	M.	24·7	24·7	Frost, 29·8.
	E.	24·8	24·10	
21	M.	23·5	23·7	N. E.; 29·4.
	E.	23·3	23·6	
22	M.	22·0	22·4	
	E.	20·3	21·7	
23	M.	20·3	20·7	S., strong; 29·3.
	E.	19·9	20·9	
24	M.	19·8	20·0	
	E.	20·8	20·8	
25	M.	21·5	20·10	S. E., gale.
	E.	22·3	22·2	,,

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1877.		ft. in.	ft. in.	
March 26	M.	23·10	23·11	
	E.	24·10	25·3	S. Wind, strong.
27	M.	26·4	26·7	,, ,,
	E.	26·11	27·5	Stormy.
28	M.	28·1	28·3	,,
	E.	28·1	28·1	
29	M.	29·3	29·2	
	E.	28·10	28·8	
30	M.	29·5	29·2	
	E.	—	—	
31	M.	28·10	28·8	
	E.	28·10	29·1	W.
April 1	M.	27·11	27·7	N. N. W., cold.
	E.	27·4	27·6	
2	M.	26·3	26·6	W. S. W.
	E.	25·4	25·7	
3	M.	24·5	25·4	Bar. falling fast; signal fly-
	E.	23·2	23·11	Bar. 29·3. [ing; wind S.
4	M.	22·9	23·11	,, 29·0.
	E.	21·4	22·1	,, ,,
5	M.	20·8	22·3	Unsettled.
	E.	19·2	19·11	,,
6	M.	19·1	20·0	,,
	E.	17·9	18·3	,,
7	M.	18·10	18·11	
	E.	18·4	18·4	
8	M.	19·10	20·0	
	E.	19·9	20·0	
9	M.	21·5	21·6	
	E.	21·4	21·7	
10	M.	23·0	23·2	
	E.	23·0	23·4	
11	M.	24·7	24·4	
	E.	24·3	24·0	Bar rising.
12	M.	26·0	25·4	N., gusty.
	E.	25·5	25·3	
13	M.	26·10	26·6	
	E.	26·0	25·11	
14	M.	27·3	26·6	S. E., strong; Bar. 30·0.
	E.	26·6	26·0	,, ,,
15	M.	—	—	
	E.	27·7	26·7	S. E., gale; Bar. 29·8.
16	M.	26·7	26·0	S. E., ,, ,, 29·8.
	E.	26·10	25·7	E. ,, ,, ,,
17	M.	25·11	25·3	E. ,, ,, ,,
	E.	25·9	25·2	E., Bar. 29·8.

Date.	Morning and Evening.	Calculations.	Observations.	Remarks. Barom. and Wind.
1877.		ft. in.	ft. in.	
April 18	M.	24·9	24·9	
	E.	24·3	24·3	
19	M.	23·3	23·3	
	E.	22·9	22·8	
20	M.	22·1	22·3	
	E.	21·4	21·4	
21	M.	21·0	21·9	S. W.; Bar. falling.
	E.	20·6	20·9	Unsettled.
22	M.	21·2	21·4	
	E.	21·2	21·3	
23	M.	22·4	22·2	
	E.	23·0	22·11	
24	M.	24·0	23·9	
	E.	24·7	24·6	
25	M.	25·11	25·7	S. E.; 29·8.
	E.	26·2	25·10	S. E.; 29·9.
26	M.	27·2	26·7	S. E., strong; 30·0.
	E.	26·11	26·7	S. E.; 29·8.
27	M.	27·6	26·11	S. E., strong; 29·8.
	E.	27·1	26·11	,, ,, 29·9.
28	M.	27·4	27·3	
	E.	27·0	27·0	
29	M.	—	—	
	E.	27·0	26·10	
30	M.	26·8	26·5	N., frosty; 29·8.
	E.	25·8	25·9	N. W.; 30·0.

XX.—Discussion of Observations for determining the Parallax of the Planetary Nebula, 37, H. IV. Made with the South Equatorial at Dunsink. By Francis Brünnow, Ph. D., F.R.A.S.

[Read, November 12, 1877.]

At the Meeting of the British Association for the Advancement of Science, held at Edinburgh in 1871, Mr. Gill read a Paper on the "Parallax of the Planetary Nebula H. IV., 37," for which he had found a value of about two seconds. However, the number of his observations was so small, that it seemed to me advisable to make a longer series of observations of this interesting object, in order to examine whether such a large parallax really existed. The observations were commenced immediately after my return home on August 13, 1871, and were continued to August 6, 1872, with some interruptions owing to my absence from the Observatory during the months of January and February, 1872, and again during part of April and May. They are, therefore, not as numerous as I could have wished, but still are sufficient to show that the nebula has no large parallax.

The nebula appears as a somewhat elliptical disk whose major axis is about half a minute, and has in its centre a well-defined point resembling a star of the eleventh magnitude. I compared this centre in declination with a star of the tenth magnitude which precedes the nebula by 25 seconds, using exactly the same method of observing as that adopted in my former series of observations on the parallax of stars. I also used a faintly illuminated field, as I could make the bisections of these faint objects more accurately with dark wires than in a dark field with bright wires. Of course, I observed only when the atmosphere was sufficiently good to show the central point distinctly.

The observations I have obtained are as follows :—

Date.	$\Delta\delta$ expressed in rev. of the screw.	Therm.	$\Delta\delta$ in seconds.	Weight.
1871.				
August 13,	6·95815	55°·0	62″·561	
,, 15,	6·95670	54 ·0	62 ·551	
,, 25,	7·02535	50 ·5	63 ·176	
,, 27,	6·98780	52 ·0	62 ·834	
September 11,	6·99955	53 ·0	62 ·939	
,, 12,	6·98115	54 ·0	62 ·773	
,, 13,	6·98390	52 ·0	62 ·799	
,, 21,	6·98320	42 ·0	62 ·813	

Date.	Δδ expressed in rev. of the screw.	Ther.	Δδ in seconds.	Weight.
1871.				
September 23,	6·95920	40°·0	62″·603	
,, 28,	6·97930	42 ·0	62 ·779	
October 7,	6·99335	39 ·5	62 ·910	
,, 20,	6·99180	41 ·0	62 ·894	
,, 21,	7·00335	44 ·5	62 ·990	
,, 24,	6·99310	43 ·5	62 ·900	
November 5,	6·99390	37 ·0	62 ·921	
,, 22,	6·98395	38 ·5	62 ·827	
December 16,	6·99230	37 ·0	62 ·907	
,, 19,	6·99590	39 ·0	62 ·933	
,, 20,	6·97100	37 ·0	62 ·716	
1872.				
January 6,	6·97640	35 ·0	62 ·767	
March 1,	7·02915	42 ·5	63 ·227	$\frac{5}{6}$
,, 8,	7·01055	37 ·0	63 ·071	
,, 14,	7·01730	39 ·0	63 ·126	
,, 17,	7·01220	39 ·5	63 ·080	
April 3,	7·00625	35 ·0	63 ·034	
,, 12,	7·01195	40 ·0	63 ·077	
,, 13,	7·00485	41 ·0	63 ·011	
May 31,	7·00490	44 ·0	63 ·004	
June 5,	6·99815	44 ·0	62 ·943	
,, 7,	7·00085	45 ·5	62 ·966	
July 14,	6·98540	56 ·0	62 ·806	
August 2,	6·99450	52 ·0	62 ·896	
,, 6,	6·99410	53 ·0	62 ·891	

The observed apparent differences of declination must first be corrected for refraction and aberration, and reduced to a mean equinox, for which I chose as epoch the beginning of the year 1872. The effect of refraction is in this case very small, and nearly constant, as is shown by the following Table, because all the observations were made at considerable altitudes:—

Hour Angle.	Corr. for Refr.	Hour Angle.	Corr. for Refr.
0^h	+ 0″·019	4^h	+ 0″·018
1	+ 0 ·018	5	+ 0 ·018
2	+ 0 ·018	6	+ 0 ·021
3	+ 0 ·018	7	+ 0 ·026

The effect of aberration, nutation, and precession, is given in the following Table, which has been computed from the formulæ on page 38 of Part I.[1] :—

Date.	Reduction to Mean $\Delta\delta$.	Date.	Reduction to Mean $\Delta\delta$.
1871.		1872.	
August 7·7,	− 0″·050	February 9·5,	+ 0″·014
,, 17·7,	0 ·044	,, 19·5,	0 ·010
,, 27·6,	0 ·038	,, 29·4,	0 ·006
Sept. 6·6,	0 ·032	March 10·4,	+ 0 ·001
,, 16·6,	0 ·026	,, 20·4,	− 0 ·005
,, 26·5,	0 ·019	,, 30·3,	0 ·010
October 6·5,	0 ·013	April 9·3,	0 ·015
,, 16·5,	0 ·007	,, 19·3,	0 ·019
,, 26·5,	− 0 ·001	,, 29·3,	0 ·023
Nov. 5·4,	+ 0 ·005	May 9·2,	0 ·026
,, 15·4,	0 ·010	,, 19·2,	0 ·028
,, 25·4,	0 ·014	,, 29·2,	0 ·029
December 5·4,	0 ·018	June 8·1,	0 ·030
,, 15·3,	0 ·020	,, 18·1,	0 ·029
,, 25·3,	0 ·022	,, 28·1,	0 ·027
,, 35·3,	0 ·022	July 8·1,	0 ·025
1872.		,, 18·0,	0 ·022
January 0·6,	0 ·022	,, 28·0,	0 ·018
,, 10·6,	0 ·021	August 7·0,	0 ·013
,, 20·5,	0 ·020	,, 17·0,	0 ·007
,, 30·5,	0 ·018	,, 26·9,	− 0 ·001

From these Tables I found the small corrections for every observation, which are given in the first two columns of the following Table, and by applying them to the observed values of $\Delta\delta$, given above, I obtained the reduced values $\Delta\delta$, which are given in the last column of the following Table :—

Date.	Refr.	Red.	Sum.	$\Delta\delta$.
1871.				
August 13,	+ 0″·018	− 0″·046	− 0″·028	62″·533
,, 15,	+ 0 ·018	− 0 ·045	− 0 ·027	62 ·524
,, 25,	+ 0 ·018	− 0 ·039	− 0 ·021	63 ·155
,, 27,	+ 0 ·018	− 0 ·038	− 0 ·020	62 ·814
September 11,	+ 0 ·018	− 0 ·029	− 0 ·011	62 ·928
,, 12,	+ 0 ·018	− 0 ·028	− 0 ·010	62 ·763

[1] Astronomical Observations made at Dunsink, 1871.

Date.	Refr.	Red.	Sum.	Δδ.
1871.				
September 13,	+ 0″·018	− 0″·028	− 0″·010	62″·789
,, 21,	+ 0 ·018	− 0 ·022	− 0 ·004	62 ·809
,, 23,	+ 0 ·018	− 0 ·021	− 0 ·003	62 ·600
,, 28,	+ 0 ·018	− 0 ·018	− 0 ·000	62 ·779
October 7,	+ 0 ·020	− 0 ·012	+ 0 ·008	62 ·918
,, 20,	+ 0 ·019	− 0 ·005	+ 0 ·014	62 ·908
,, 21,	+ 0 ·022	− 0 ·004	+ 0 ·018	63 ·008
,, 24,	+ 0 ·020	− 0 ·002	+ 0 ·018	62 ·918
November 5,	+ 0 ·023	+ 0 ·005	+ 0 ·028	62 ·949
,, 22,	+ 0 ·018	+ 0 ·013	+ 0 ·031	62 ·858
December 16,	+ 0 ·018	+ 0 ·020	+ 0 ·038	62 ·945
,, 19,	+ 0 ·019	+ 0 ·021	+ 0 ·040	62 ·973
,, 20,	+ 0 ·018	+ 0 ·021	+ 0 ·039	62 ·755
1872.				
January 6,	+ 0 ·023	+ 0 ·021	+ 0 ·044	62 ·811
March 1,	+ 0 ·025	+ 0 ·005	+ 0 ·030	63 ·257
,, 8,	+ 0 ·023	+ 0 ·002	+ 0 ·025	63 ·096
,, 14,	+ 0 ·024	− 0 ·001	+ 0 ·023	63 ·149
,, 17,	+ 0 ·022	− 0 ·004	+ 0 ·018	63 ·098
April 3,	+ 0 ·018	− 0 ·012	+ 0 ·006	63 ·040
,, 12,	+ 0 ·018	− 0 ·016	+ 0 ·002	63 ·079
,, 13,	+ 0 ·018	− 0 ·017	+ 0 ·001	63 ·012
May 31,	+ 0 ·018	− 0 ·030	− 0 ·012	62 ·992
June 5,	+ 0 ·018	− 0 ·030	− 0 ·012	62 ·931
,, 7,	+ 0 ·018	− 0 ·030	− 0 ·012	62 ·954
July 14,	+ 0 ·018	− 0 ·023	− 0 ·005	62 ·801
August 2,	+ 0 ·018	− 0 ·015	+ 0 ·003	62 ·899
,, 6,	+ 0 ·018	− 0 ·014	+ 0 ·004	62 ·895

If we take then $\Delta\delta_0$ as a mean value of $\Delta\delta$, $d\Delta'$ as the difference of the proper motions of the star and nebula, and denote the difference of the parallax of the nebula from that of the star by π, that of the constants of aberration for the two objects by κ every observation will give us an equation of the form:

$$0 = \Delta\delta_0 - \Delta\delta + d.\,\Delta\delta_0 + t.\,d\Delta' - b.\,R.\,\cos(\odot + B).\,\pi - b.\,\sin(\odot + B).\,\kappa.$$

The values of the constant quantities B and b were found from the well-known formulæ

$$B = 270^\circ - 19', \qquad b = 1{\cdot}0000,$$

the latter value being equal to unity, because the nebula is close to the North Pole of the Ecliptic.

Taking, then, for $\Delta\delta_0$ the value 62″·900, and computing the values of the coefficients of $d\Delta'$, κ, and π for every observation, I obtained the following system of equations of condition :—

Date.	Equations.				Residual Errors.
1871.					
Aug. 13,	$d.\Delta\delta_0 - 0{\cdot}382\, d\Delta' - 0{\cdot}778\, \kappa - 0{\cdot}637\, \pi = -0''{\cdot}367$				− 0″·260
,, 15,	− 0·376	− 0·798	− 0·609	− 0 ·376	− 0 ·268
,, 25,	− 0·349	− 0·888	− 0·465	+ 0 ·255	+ 0 ·366
,, 27,	− 0·343	− 0·903	− 0·434	− 0 ·086	+ 0 ·026
Sept. 11,	− 0·303	− 0·982	− 0·191	+ 0 ·028	+ 0 ·138
,, 12,	− 0·300	− 0·985	− 0·175	− 0 ·137	− 0 ·029
,, 13,	− 0·297	− 0·988	− 0·158	− 0 ·111	− 0 ·003
,, 21,	− 0·275	− 1·000	− 0·022	− 0 ·091	+ 0 ·013
,, 23,	− 0·270	− 1·000	+ 0·013	− 0 ·300	− 0 ·198
,, 28,	− 0·256	− 0·995	+ 0·099	− 0 ·121	− 0 ·024
Oct. 7,	− 0·231	− 0·968	+ 0·250	+ 0 ·018	+ 0 ·106
,, 20,	− 0·196	− 0·888	+ 0·458	+ 0 ·008	+ 0 ·076
,, 21,	− 0·193	− 0·879	+ 0·473	+ 0 ·108	+ 0 ·175
,, 24,	− 0·185	− 0·854	+ 0·517	+ 0 ·018	+ 0 ·079
Nov. 5,	− 0·152	− 0·727	+ 0·681	+ 0 ·049	+ 0 ·089
,, 22,	− 0·106	− 0·495	+ 0·858	− 0 ·042	− 0 ·039
Dec. 16,	− 0·040	− 0·092	+ 0·980	+ 0 ·045	− 0 ·006
,, 19,	− 0·032	− 0·039	+ 0·983	+ 0 ·073	+ 0 ·014
,, 20,	− 0·029	− 0·021	+ 0·983	+ 0 ·145	− 0 ·206
1872.					
Jan. 6,	+ 0·017	+ 0·278	+ 0·945	− 0 ·089	− 0 ·185
March 1,	+ 0·069	+ 0·952	+ 0·304	+ 0 ·357	+ 0 ·190
,, 8,	+ 0·188	+ 0·982	+ 0·188	+ 0 ·196	+ 0 ·026
,, 14,	+ 0·204	+ 0·996	+ 0·086	+ 0 ·249	+ 0 ·079
,, 17,	+ 0·212	+ 0·999	+ 0·034	+ 0 ·198	+ 0 ·029
April, 3,	+ 0·259	+ 0·966	− 0·257	+ 0 ·140	− 0 ·021
,, 12,	+ 0·284	+ 0·975	− 0·404	+ 0 ·179	+ 0 ·025
,, 13,	+ 0·286	+ 0·908	− 0·420	+ 0 ·112	− 0 ·040
May 31,	+ 0·417	+ 0·325	− 0·960	+ 0 ·092	+ 0 ·008
June 5,	+ 0·431	+ 0·244	− 0·984	+ 0 ·031	− 0 ·044
,, 7,	+ 0·437	+ 0·213	− 0·992	+ 0 ·054	− 0 ·019
July 14,	+ 0·538	+ 0·393	− 0·935	− 0 ·099	− 0 ·116
Aug. 2,	− 0·590	− 0·659	− 0·763	− 0 ·001	+ 0 ·002
,, 6,	− 0·601	− 0·708	− 0·716	− 0 ·005	+ 0 ·001

In solving these equations according to the method of least squares, the weight of all observations, with the exception of that of March 1, 1872, which is incomplete, has been taken equal to 1. I obtained

thus the following final equations for determining the unknown quantities:—

$$
\begin{array}{rrrrrrrrrrrr}
+ & 33{\cdot}0000 & d.\Delta\delta_0 & + & 0{\cdot}3172 & \kappa & - & 8{\cdot}2603 & d.\Delta' & - & 1{\cdot}2703\,\pi & = + 0''{\cdot}2400 \\
+ & 0{\cdot}3172 & ,, & + & 3{\cdot}1428 & ,, & + & 4{\cdot}6399 & ,, & - & 2{\cdot}5263 & ,, = + 0\ {\cdot}7179 \\
- & 8{\cdot}2603 & ,, & + & 4{\cdot}6399 & ,, & + & 20{\cdot}5923 & ,, & + & 0{\cdot}1074 & ,, = + 2\ {\cdot}4580 \\
- & 1{\cdot}2703 & ,, & - & 2{\cdot}5263 & ,, & + & 0{\cdot}1074 & ,, & + & 12{\cdot}4156 & ,, = + 0\ {\cdot}3016.
\end{array}
$$

The solution of these equations gives the following values:—

$$
\begin{aligned}
d.\Delta\delta_0 &= + 0''{\cdot}036 \\
d\Delta' &= + 0\ {\cdot}0978 \\
\kappa &= + 0\ {\cdot}112 \\
\pi &= + 0\ {\cdot}047.
\end{aligned}
$$

The errors which remain in the equations of condition after the substitution of these values are given in the last column of the preceeding Table.

The squares of the errors are thereby reduced from 0″·899 to 0·532, which gives for the probable error of one observation the value ± 0″·09, and for the probable errors of the quantities above:—

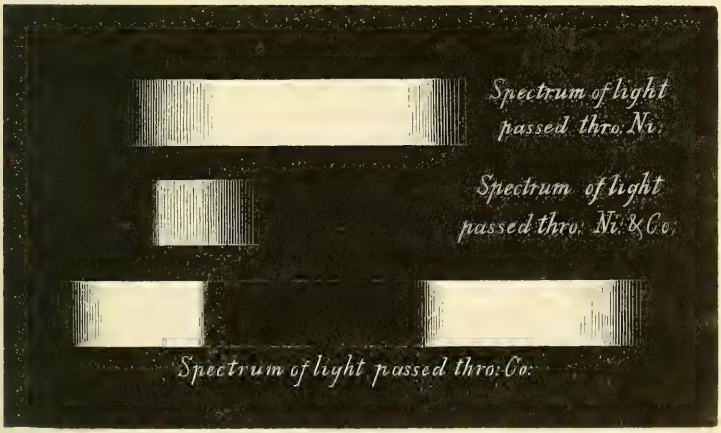
$$
\begin{aligned}
(d.\Delta\delta_0) \ .\ .\ .\ .\ &\pm 0''{\cdot}018 \\
d\Delta' \ .\ .\ .\ .\ &\pm 0\ {\cdot}0759 \\
\kappa \ .\ .\ .\ .\ &\pm 0\ {\cdot}029 \\
\pi \ .\ .\ .\ .\ &\pm 0\ {\cdot}030.
\end{aligned}
$$

XXI.—On the Colour Relations and Colorimetric Estimation of Nickel and Cobalt. By Thomas Bayley, Associate R. C. Sc. I.

[Read, November 12, 1877.]

The fact will have been observed by chemists that solutions of nickel and cobalt salts are so far complementary in colour that, when they are mixed together, the resulting liquid, if moderately dilute, is hardly to be distinguished from pure water. I conceived this fact might be made the basis of a method for estimating nickel and cobalt, and, therefore, undertook the following experiments.

A large hollow prism, filled with a moderately strong solution of a nickel or cobalt salt, was placed immediately in front of the slit of the spectroscope, and the thickness of the liquid traversed by the light was regulated by moving the prism until the eye could most clearly determine the dark absorption band caused by the metal in solution. On referring to the accompanying diagram, which shows the absorption spectra of the two metals, it will be seen that cobalt and nickel are almost exactly complementary in their relations to light. The black band of cobalt is well defined at the edges, especially at the end nearest to the red, while the absorption bands of nickel are not so sharply defined, but fade away at each end. If the spectra were exactly complementary, on superimposing the nickel spectrum upon the cobalt spectrum, the dark part on the one would exactly cover the light part on the other. This, however, though nearly the case, is not exactly so, for the light band in the nickel spectrum overlaps the dark cobalt band at the end nearest to the red, although with diminished brilliancy. Consequently, when we employ a mixture of nickel and cobalt salts in solution, we do not get a uniformly dark



spectrum, but an excess of light coming through at the part where the overlapping occurs, as seen in the diagram. This is why the so-

lution obtained by mixing strong solutions of nickel and cobalt is not grey, but reddish brown in colour.

Having so far demonstrated the complementary character of the two metals, I next endeavoured to find in what proportions they must be mixed in order to neutralize each other. For this purpose a tall glass cylinder (150 c. c. capacity), in which ammonia is estimated by Nessler's method, was employed. Dilute standard solutions of pure nickel and cobalt having been carefully prepared, a measured quantity of cobalt solution was placed in the cylinder, and the nickel added from a burette, until the neutral point was reached. It is difficult by this method to distinguish the exact point of neutrality, but easy to determine that the colour coefficient of nickel with regard to cobalt lies between 3·1 and 3·2. That is to say, if a quantity of cobalt in solution be mixed with a solution containing 3·1 times its weight of nickel, the cobalt colour will slightly predominate in the mixture, which will have a reddish tinge; while, if a solution containing 3·2 times its weight of nickel be added, the nickel colour will be slightly in excess, and the solution will have an olive green tinge. It is only with dilute solutions containing not more than about 2·5 grams of the metals per litre, that it is possible to determine the coefficient with this accuracy.

I now sought for some method of indicating more exactly the neutral point. After several attempts it was found that the addition of ammonium carbonate to the solution of the two metals affords a means of determining whether the slightest excess of either metal is present.

If we take 25 c. c. of solution containing ·03125 gram of cobalt, and add to this 39·25 c. c. of solution containing ·098125 gram of nickel, the resulting liquid appears perfectly colourless. If we now dilute the mixed solutions to 100 c. c. and transfer 25 c. c. of that solution, containing ·0078125 gram of cobalt, and ·02453125 gram of nickel, to a tall glass jar, add 25 c. c. of the solution of ammonium carbonate, described hereafter, and then dilute to 150 c. c., the result is a liquid of deep purple colour. If we repeat this experiment, using in the first instance ·03125 gram of cobalt, and ·099375 gram of nickel, the colour of the 150 c. c. is not purple, but of a distinct blue colour. The ammonium carbonate for this purpose must be neutral, as the excess of either base or acid destroys the delicacy of the reaction.

The solution of neutral carbonate $(NH_4)_2\,CO_3$ was prepared as follows. A few ounces of the commercial carbonate having been dissolved in water, 10 c. c. of the solution were neutralized by standard solution of sulphuric acid. The quantity of NH_3 in the 10 c. c. was found to be ·085 gramme. The quantity of CO_2 in an equal quantity of the solution was found to be in two experiments ·348 gram, and ·350 gram (mean ·349 gram): the amount of CO_2 required to form the neutral carbonate with ·085 gram of NH_3 being ·110, it follows that there was an excess of CO_2 equal to ·259 gram in every 10 c. c. of the original solution of commercial carbonate. To neu-

tralize this, 18 grams of ammonia were required to be added to a litre of the commercial carbonate solution. This was furnished by 61·7 c. c. of ammonia solution (of sp. gr. ·880).

I next endeavoured to determine whether the nature of the salt of nickel or cobalt has any effect on the reaction. For this purpose the following solutions were prepared:—

$Co\ Cl_2$	1 c. c.	= ·00125	grm. Co.
$Ni\ Cl_2$	1 c. c.	= ·0025	grm. Ni.
$Ni(NO_3)_2$	1 c. c.	= ·0025	grm. Ni.
$Ni\ SO_4$	1 c. c.	= ·0025	grm. Ni.
$Co\ (NO_3)_2$	1 c. c.	= ·00125	grm. Co.
$Co\ SO_4$	1 c. c.	= ·00125	grm. Co.

The method of proceeding was as follows:—In each of five cylinders 25 c. c. of the standard solution of cobaltous chloride were placed; to the first cylinder 39 c. c. of the solution of nickelous chloride were added; to the second cylinder 39·25 c. c., and so on; 40 c. c. of nickelous chloride being added to the fifth cylinder. Each cylinder was then made up to 100 c. c., and 25 c. c. out of each 100 c. c., were placed in a second series of cylinders. To each of the second series neutral ammonium carbonate (25 c. c.) was added, and then sufficient water to make 150 c. c. The results are expressed in the following Table:—

Cylinder.	Co used.	Ni used.	Colour.	Ratio of Ni to Co.
(1)	·03125 grm.	·09750 grm.	purple.	3·12
(2)	·03125 ,,	·098125 ,,	slightly purple.	3·14
(3)	·03125 ,,	·098750 ,,	between 2 & 4.	3·16
(4)	·03125 ,,	·099375 ,,	slightly blue.	3·18
(5)	·03125 ,,	·10000 ,,	blue.	3·20

In two experiments, using in the first solutions of $Co\ Cl_2$ and $Ni\ SO_4$, and in the second solutions of $Co\ Cl_2$ and $Ni\ (NO_3)_2$, I obtained exactly the same results, so that the foregoing Table expresses the results of these experiments. Subsequently experiments were made with the same quantities of the metals in the following combinations, $Co\ (NO_3)_2$ with $Ni\ SO_4$, $Ni\ (NO_3)_2$ and $Ni\ Cl_2$ $Co\ SO_4$ with $Ni\ (NO_3)_2$, $Ni\ SO_4$ and $Ni\ Cl_2$.

The results of these latter experiments were exactly the same as those of the first experiments, so that the Table does equally well to express them also.

If the cylinders, after the addition of the ammonium carbonate, be allowed to stand, the differences of tint disappear in a few hours, and a uniform deep purple red tint is produced. This is caused by the cobalt

absorbing oxygen from the air to form the double compounds of cobalt and ammonia. A small quantity of a sulphite destroys the reaction, as it changes the tint to a deep brown. Thiosulphates and some other reducing agents do not act in this way.

These experiments lead to the conclusion that the colour coefficient of nickel with regard to cobalt is 3·16, in all cases, or, in other words, that the tint of nickel and cobalt solutions is independent of the acid radical in combination with the metals, and depends only upon the metal in solution. It is evident that nickel and cobalt may be estimated by means of this reaction. As an example of its application to this purpose, I give the following account of the manner in which small quantities of nickel may be estimated.

The nickel must be dissolved in an acid, and the solution diluted to any convenient quantity, *e. g.*, 50 or 100 cubic centimetres. Into each of three cylinders ·0078125 grm. of Co as $Co Cl_2$ is placed. This amount of cobalt is afforded by 6·25 c. c. of the standard $Co Cl_2$ solution. Calling the cylinders No. 1, No. 2, and No. 3, we place in No. 1, ·024531 grm. of nickel in solution, and in No. 3, ·0248458 grm. To the three cylinders we then add 25 c. c. of the standard ammonium carbonate. Cylinder No. 2, which contains only cobalt solution and ammonium carbonate, is then made up nearly to 150 c. c., and No. 1 and No. 3 are filled up to that quantity. Cylinder No. 1 has then a purple tinge, while cylinder No. 3 has a blue tinge. By adding from a burette the solution whose strength we wish to determine to No. 2, until its tint is intermediate between No. 1 and No. 3, we make with great accuracy the required determination. In all cases the cylinders should be held, whilst under comparison, with their lower extremities at some inches distance above a sheet of white paper. Three experiments, that by no means reached the highest limit of accuracy, gave the following results :—

Ni in solution.		Ni found.
·02469 grm.	(1)	·02425
	(2)	·02475
	(3)	·02500
		·02466 = mean.

It is evident that a similar plan of estimating cobalt would be still more accurate on account of the higher colour efficiency of that metal.

The partially opaque brown solution obtained by mixing *strong* solutions of nickel and cobalt might, I think, be used for making standards for the purposes of colorimetrical analysis. For instance, the brown solution mixed with a few drops of potassic bichromate cannot be distinguished from Nesslerised ammonia. Probably the tests used to compare the solutions of steel, in Eggertz's process for the estimation of carbon, might be made in a similar manner. They would have the advantage of being permanent.

XXII.—On Schutzenberger's Process for the Volumetric Estimation of Oxygen in Water.

By Christopher Clarke Hutchinson, Royal Exhibitioner, Royal College of Science.

[Read, December 10, 1877.]

In judging of the character of a water for domestic uses, one of the most important points to be ascertained is, the question of its pollution by sewage and other deleterious matters.

The determination of this pollution, its extent and nature, is at present rather unsettled. It is, however, believed by many chemists that a contamination, such as referred to, will exercise an effect upon the gaseous bodies held in solution in a water. It is the opinion of many, that the relative quantity of oxygen present in a water affords the key to its deterioration by organic matter; because it is unlikely that a large quantity of oxygen can be held in solution by a water containing oxidizable matter. Waters which contain their normal proportion of oxygen, in relation to their other gaseous constituents, would be regarded as free from sewage and decaying matter; a diminution in the quantity of oxygen would indicate a corresponding increase in the amount of injurious matter present.

The late Dr. Miller's analyses of the gases present in the water of the Thames, at various points, clearly proved that as the amount of sewage *increased*, the amount of carbonic acid increased, and the amount of oxygen *decreased*.

The Rivers' Pollution Commissioners state in their sixth Report that the proportion of oxygen in water is deprived of much importance, since it has been discovered that deep well waters, which cannot contain putrescent organic matter, contain little or no dissolved oxygen. The absence of oxygen in deep well waters may, however, be owing to its having oxidized and destroyed the organic matter the water previously contained, during its percolation through the strata.

In the presence of this conflicting testimony, I was induced to undertake an investigation, in the hope of throwing some light upon this important question—whether or not the amount of oxygen present is, or is not, an indication of the freedom of a water from injurious organic bodies.

In commencing the inquiry I was desirous of employing some accurate, and yet rapid, method, for the estimation of the oxygen present; for although the gasometric operations by Bunsen's method leave nothing to be desired in point of accuracy, yet on account of their somewhat tedious nature some other plan, if even slightly less accurate, but at the same time more rapid, would be desirable.

Such a method as this I thought might be afforded by the process devised by Schutzenberger for the volumetric estimation of oxygen in

oxygenated liquids.[1] As the estimation is made without the removal of the oxygen by boiling, and in the condition in which it exists in the water, such a plan would seem to be more desirable than its expulsion from the liquid, together with the other gases held in solution, and their subsequent determination.

I now proceed to give the results I have obtained by means of this volumetric process.

Briefly described, the method consists in adding a known volume of the water under experiment to a solution which is capable of being oxidized (accompanied by a change of colour due to such oxidation) by the oxygen held in solution. The extent to which this has occurred is then determined, by the addition of a powerful reducing agent, which, acting upon the coloured compound so formed, reduces it to its former condition—the amount necessary being, of course, indicated by the reverse change of colour to that which occurred in the first instance. This last solution being standardized in terms of the oxygen it is capable of taking up, from the amount used in the experiment we arrive at the volume of oxygen contained in the volume of water taken.

The re-agents used I will now describe, with the method, and proportions for their preparation I found most advantageous.

The reducing agent used is sodium hyposulphite—not the commonly so-called "hyposulphite," but the sodium salt of the acid $H_2 SO_2$; its formula as given by Schutzenberger is $Na H SO_2$. I prepared this as follows:—A concentrated solution of caustic soda ($Na HO$), specific gravity 1·4, was taken; sulphurous anhydride (SO_2) was passed through it, until the liquid was thoroughly saturated, and smelt strongly of the gas. The yellow liquid (which was kept cool during the process of saturation by immersion in cold water) is sodium bisulphite ($Na H SO_3$); it increased slightly in bulk, and was reduced to the specific gravity of about 1·34. 100 grammes (75 cub. cents.) of this solution was then briskly agitated in a flask with 6 grammes of powdered zinc, air being excluded; an elevation of temperature occurred, the bisulphite being converted partly into the hyposulphite, together with the formation of sodium sulphite and zincic sulphite, according to the following equation:

$$3\,Na H SO_3 + Zn = Na H SO_2 + Na_2 SO_3 + Zn SO_3 + H_2O.$$

After agitation for about five minutes, the liquid was allowed to cool; 400 cub. cents. of water recently boiled were added; 35 cub. cents. of milk of lime, containing 200 grammes of CaO per litre, were also added, and the mixture allowed to stand until clear, when it was decanted off into well-stoppered bottles, and kept in the dark. The lime solution not only precipitates the zinc salt, but also

[1] *Bulletin de Chemie et Physique*, vol. [illegible].

renders the solution less absorbent of free oxygen, although it acts very rapidly upon dissolved oxygen. Before use this was further diluted with three times its bulk of distilled water, recently boiled.

The liquid recommended by which the change of colour detects the completion of the process is either carmine indigo (sulphindigotate of soda, $C_8 H_4 Na NOSO_3$), or Coupier's aniline blue. 10 grammes of the carmine indigo are recommended to be dissolved in one litre of water, the product being kept in well-stoppered bottles also in the dark.

An ammoniacal solution of pure copper sulphate is also recommended to be made, containing 4·46 grammes (or, more correctly, 4·471 grammes) of the crystallized salt per litre. This is to be used for the standardization of the above two solutions.

Since the reducing agent is so sensitive to the presence of oxygen, it is necessary to make the estimations in an atmosphere of pure hydrogen. To ensure the purity of the hydrogen, I passed it through a solution of nitrate of silver, in addition to the sulphuric acid, and the tube containing pieces of caustic potash.

We begin by finding the volume relation between the indigo and hyposulphite. The burettes of the apparatus are filled, one with indigo carmine solution, the other with hyposulphite; a rapid current of hydrogen is passed through the apparatus, a small quantity of warm distilled water added, and this coloured by the addition of a small quantity of indigo. We now add cautiously the hyposulphite; the blue solution turns first green, and finally to a clear yellow tint. If the whole of the air has been expelled from the apparatus, the yellow tint will remain unchanged; the slightest trace of oxygen causes the surface of the liquid to become blue. A known volume of indigo (25 cub. cents.) is now added, and the hyposulphite solution again run in until the yellow tint appears, indicative of the reduction of the whole of the indigo. The colour change is exceedingly sharp, one drop being sufficient to change the colour from green to yellow. If the solution be acid, the blue colour changes first to red, and finally the yellow tint appears.

We next require to find the reducing power of the hyposulphite in terms of oxygen, finding from this the amount of oxygen any volume of the indigo will yield. This being a stable solution, the hyposulphite (being liable to change) can be readily standardized at any future time.

Two methods can be used, by which this reducing power can be found:

First. By finding the quantity necessary to reduce the ammonia copper solution, *i.e.*, the amount which brings the blue solution to a colourless state, by the reduction of the cupric to cuprous oxide, 10 cub. cents. of this solution yields 1 cub. cent. of oxygen (0°C. 760 m.m.s. pres.) to the reducer. 25 cub. cents. are operated on in a smaller apparatus, similar to the one used for the water estimations. I find, however, that the colour change in this plan is so inde-

finite, and difficult, even to the practised eye, to detect, that the exact point cannot be determined with any degree of certainty.

The second method consists in obtaining a pure water saturated with air, and then finding the quantity of hyposulphite capable of abstracting the whole of its oxygen.

This water is obtained by agitating in a large flask about one litre of distilled water with free access of air; the agitation is continued for about a quarter of an hour. To find the amount of oxygen in a given volume of the water, I made the following formula, from the consideration of the relative quantity of oxygen present in the air, and its coefficient of absorption in water:

$$v = 0{\cdot}0262 \times \alpha_{t^\circ} \times V \times \frac{P}{95},$$

in which we have

v = vol. of oxygen in cub. cents. at 0° C. and 760 m.m.s. pres.

α_{t° = coefficient of absorption of oxygen in water at temp. t° C., given by Bunsen's Tables.

V = volume of water employed, temp. t° C.

P = barometric pressure in m.m.s.

The relation between the saturated water and the hyposulphite is found in exactly the same way as the method, hereafter described, for the oxygen determination in waters. I found that, although the hyposulphite solution was about the strength recommended, the volume relation between it and the indigo, instead of being one to ten, was equal. As the indigo solution thus appeared ten times too concentrated, I further diluted it for use.

The following is an example of standardization by the above method. The apparatus was in every way regulated as described for water estimations:—

Comparison of Hyposulphite and Indigo.

Mean of five experiments gave

25 cub. cents. indigo = 7 cub. cents. hyposulphite.

Comparison of Saturated Water and Hyposulphite.

Mean of five experiments gave

75 cub. cents. of water = 2·4 cub. cents. hyposulphite,

from which is found

25 cub. cents. indigo = 218·75 cub. cents. of water.

temperature of water = 12·6° C.

barometric pressure = 744 m.m.s.

We therefore have

$$v = 0{\cdot}0262 \times 0{\cdot}031024 \times 218{\cdot}75 \times \frac{744}{95} = 1{\cdot}392;$$

therefore

25 cub. cents. indigo = 1·392 cub. cents. oxygen.

I made determinations on different days, at different conditions of temperature and pressure. The following shows the quantity of oxygen 25 cub. cents. of indigo was calculated to yield in each case:

Temp. 12·6° C. Pressure, 744 m.m.s.	= 1·392 cub. cents.
Temp. 15·5° C. Pressure, 771 m.m.s.	= 1·448 ,, ,,
Temp. 14·75° C. Pressure, 752 m.m.s.	= 1·354 ,, ,,
Mean, ...	= 1·398.

The small amount of variation, under widely different conditions, shows this method of standardization to be a reliable one.

I now proceed to give the method for the estimation of oxygen contained in a water. Owing to the change which the hyposulphite undergoes, it is necessary that a comparison between it and the indigo should be made each day. After this has been done, and the apparatus freed from air by means of the hydrogen, 200 cub. cents. of warm water (temp. about 50° C.) are then added; 50 cub. cents. of indigo are now run in. This I usually effected in portions of about 15 cub. cents. at a time, decolourizing each portion by means of the hyposulphite, thus utilizing this step for the comparison of the two re-agents; effecting thereby a saving of time and material. The liquid in the apparatus being now brought to the yellow neutral tint, a measured volume of the water under experiment is added—75 cub. cents. I found a convenient quantity—taking care that no air is admitted at the same time. The bleached indigo will now become re-oxidised, turning from yellow to blue, in proportion to the amount of oxygen present in the water. The hyposulphite is now cautiously added, until we again arrive at the yellow tint, free from green; a single drop of the re-agent is sufficient to effect the colour change at the proper point. From the quantity used, we find the amount of oxygen present in this 75 cub. cents. of water. The operation can be repeated over again on

another volume of the water, until the apparatus becomes inconveniently full. I usually made from four to six such experiments in each case. The temperature of the apparatus must be kept at about 50° C., by the addition of warm water at intervals; the amount of hyposulphite required becomes gradually less as the apparatus cools, giving the results too low.

To test the accuracy of the method, I took a measured volume of the same water at the time of the experiments, expelled the gases by boiling, collected this gaseous mixture, and determined its volume and composition by the usual methods of Bunsen's gasometric analysis.

The following examples are taken, to illustrate the method of analysis.

Volumetric Method.

Mean of four determinations gave

25 cub. cents. indigo = 8·21 cub. cents. hyposulphite.

This quantity of indigo we before found to yield 1·398 cub. cents. of oxygen. Therefore

8·21 cub. cents. hyposulphite = 1·398 cub. cents. of oxygen.

Mean of five determinations gave

3·55 cub. cents. hyposulphite = 75 cub. cents. of water.

From this we find the quantity of oxygen contained in 2·420 litres of water—the volume used in the gasometric method.

2·420 litres of water contain 19·505 cub. cents. of oxygen.

Gasometric Method.

Volume used, ... 2·420 litres.
Temperature of water, . . . 13° C.

	Volume.	Temperature in o° C.	Pressure in m.m.s.	Column of Mercury above that in trough, in m.m.s.	Corrected Volume at o° C. and 760 m.m.s. pres.
Total vol. of Gas evolved, .	302·56	13·9	737	268·8	237·719
After absorption of CO_2, .	316·149	14·9	745	229·2	193·959
After the admission of H, .	503·6	14·4	765	55·2	439·066
After explosion, ...	325·96	12·4	771	230·5	217·337

Percentage Volume Composition.

Carbonic acid,	18·408
Oxygen,	31·091
Nitrogen,	50·500
Total,	99·999

Absolute Volume Composition in Cub. Cents.

Carbonic acid,	10·238
Oxygen,	17·294
Nitrogen,	28·087
Total,	55·619

	Cub. Cents.
Volume of oxygen by Volumetric method,	19·505
,, ,, ,, Gasometric ,,	17·294
Excess given by Volumetric method,	2·211

Other samples from the same source were also experimented upon, the results being variable.

Water of a different character to this last was also experimented upon, with the following result:—

Volumetric Method.

Mean of three determinations gave

25 cub. cents. indigo = 7·25 cub. cents. hyposulphite;

therefore

7·25 cub. cents. hyposulphite = 1·398 cub. cents. oxygen.

Mean of four determinations gave

3·42 cub. cents. hyposulphite = 75 cub. cents. water.

From this we find

2·420 litres of water contain 12·486 cub. cents. of oxygen.

Gasometric Method.

Volume used, ... 2·420 litres.
Temperature of water, . . . 11° C.

	Volume.	Temperature in o° C.	Pressure in m.m.s.	Column of Mercury above that in trough, in m.m.s.	Corrected Volume at o° C. and 760 m.m.s. pres.
Total vol. of Gas evolved, .	612·73	8·4	736·5	211·8	403·95
Gas used, ...	369·04	8·4	736·5	211·8	243·294
After absorption of CO_2, .	240·16	8·8	729·5	327·5	123·063
After admission of H, . .	364·97	8·8	729·5	187·5	253·313
After explosion, ...	261·2	8·7	729·5	296	141·584

Percentage Composition.

Carbonic acid, ...	49·418
Oxygen, ...	15·308
Nitrogen, ...	35·274
Total, ...	100·000

Absolute Volume Composition in Cub. Cents.

Carbonic acid, ...	46·715
Oxygen, ...	14·471
Nitrogen, ...	33·343
Total, ...	94·529

Volume of oxygen by Volumetric method,	12·486
,, ,, ,, Gasometric ,, ,	14·471
Difference, ...	1·985

In this case the Volumetric method shows a *less* volume of oxygen than the Gasometric method. This, I think, is attributable to the

large quantity of carbonic acid present; for, as Schutzenberger points out, when an acid is present in appreciable quantity, even such a weak acid as carbonic acid, the results given are invariably too low; hence this method would not be applicable, with any degree of accuracy, to waters in which a large quantity of carbonic acid is present.

I made numerous determinations, from which the two foregoing examples are selected; but none of them showed any trustworthy results; in some cases the volume of oxygen obtained being in excess, and in others less than that obtained by the Gasometric method.

The variability of the results led me to inquire into the source of these discrepancies, and how they might be avoided.

Noticing that a change of colour in the yellow neutral tint seemed to occur to a greater extent than it should do on the addition of recently boiled distilled water, I made the following experiments.

Distilled water was boiled in a flask fitted with a cork and exit valve so as to avoid contact with air, for over four hours. The apparatus was prepared as usual with indigo and hyposulphite, the temperature being kept at 50° C. The boiled water, which was kept in well-stoppered bottles, was then added in successive portions of 75 cub. cents. at a temperature of 55° C. On each addition a blue colouration was produced in the yellow neutral liquid, just as if oxygen had been absorbed by the reduced indigo. The amount of colour change was determined as usual by the addition of hyposulphite. The mean of five experiments showed that 2·9 cub. cents. were necessary to bring back the yellow tint. This quantity was found to be equivalent to 3·86 cub. cents. of indigo, or 0·201 cub. cents. of oxygen.

Unwilling to think that this was due to oxygen which had been left unexpelled by ebullition, I boiled recently-distilled water in long-necked flasks, fitted with corks and exit valves, for over five hours. The apparatus was prepared as usual, but in this case water at 100° C. was used, and the body of the apparatus immersed in water kept at 100° C. Portions of 75 cub. cents. of water were removed from the flasks whilst in a state of ebullition, and introduced into the apparatus; each addition caused a change of colour from yellow to blue. The mean of five experiments showed that 1·25 cub. cents. of hyposulphite was necessary to destroy the colour.

1·25 cub. cents. hyposulphite = 1·66 cub. cents. indigo = 0·08 cub. cents. of oxygen.

After boiling for over six hours, the water was allowed to cool, out of contact with the air, and in withdrawing portions from it coal gas was aspirated in, instead of air, so as to avoid as far as possible contact with oxygen.

The same experiments were tried at the ordinary temperature (16·75° C.), and the same volume of water (75 cub. cents.) used. The mean of four experiments gave the colour change equivalent to 1·3 cub. cents. of hyposulphite = 1·56 cub. cents. of indigo, or 0·087 cub. cents. of oxygen.

The same experiments were now made at the temperature 0°C., by

cooling the boiled water previous to its addition, and immersing the apparatus in a bath cooled by a mixture of ice and salt. The results in this case were variable, the introduction of 75 cub. cents. of water requiring from 0·9 to 2·4 of the hyposulphite. I found this to be due to the length of time the apparatus was allowed to stand in the bath, after the introduction of the water. The longer the time, the less the quantity of the re-agent required to destroy the blue tint produced. To make certain that such a change did occur, I brought the liquid to the yellow tint, and then added a few drops of indigo, so as to produce a distinct green colour. On allowing the apparatus to stand in the bath, this gradually disappeared. I tried this several times, adding variable quantities of indigo in excess; but in all cases (within certain limits), when allowed to stand in the cold water, the green colour was gradually replaced by the yellow tint, just as if a quantity of hyposulphite had been added.

I attempted to remove these errors by a modification in the method of procedure.

The burette used for the indigo was replaced by a larger one (100 cub. cents. capacity). After placing in the apparatus a quantity of indigo solution, expelling the air, and bringing to the neutral point as usual, a known excess of the hyposulphite was added. Saturated water, as before described, was then added from the large burette, so as to oxidize the excess of hyposulphite, and just tinge the liquid green. From the volume required, by using the formula before given, the volume of oxygen contained in this can be found; hence the equivalence of the excess of hyposulphite in terms of oxygen. The same operation is performed with the water under experiment acting upon the same excess of hyposulphite. The relation between the volume used and that of the saturated water gives the amount of oxygen in the liquid. Any errors resulting from change in the solution would thus be eliminated, and the calculations simplified. On trying this method, I did not find the results any more satisfactory than the original method, although performed with the greatest care: they gave quantities in excess of that given by the Gasometric method. Thus, in 2·420 litres of water,

	Cub. Cents.
Volumetric modification gave, ...	15·133
Gasometric method, ...	12·650
Excess, ...	2·483

Although this Volumetric method possesses the great merit of exceeding rapidity, yet the many precautions necessary to be taken greatly detracts from the value and reliability of the results. It seems to be better suited for the determination of oxygen in small rather than in large quantities of a liquid, such as are desirable in water estimations. It is also valuable as a means of showing whether it would be desirable to estimate the amount of oxygen present in a water, by the more

accurate methods. The process adopted by Schutzenberger for checking the results appears to have been, submitting the liquid to the action of the mercury pump for fifteen or twenty minutes. I do not think this is sufficient, for, in expelling the mixed gases from a water by boiling, I have found that traces of gas are given off even after a considerable period.

One great drawback is the considerable amount of change the hyposulphite solution undergoes, even when excluded from the air and kept in the dark. The following give the volume ratios between it and the indigo, as taken on different days, showing the extent of this change :—

Oct.	23rd.—25	cub. cents.	indigo	=	7	cub. cents.	hyposulphite.
,,	25th.—25	,,	,,	,,	=	7·84	,,	,,	,,
,,	27th.—25	,,	,,	,,	=	9·8	,,	,,	,,
Nov.	1st.—25	,,	,,	,,	=	13	,,	,,	,,
,,	6th.—25	,,	,,	,,	=	20·75	,,	,,	,,

These investigations were carried out in the Chemical Laboratories of the Royal College of Science, under the supervision of Professor Galloway.

XXIII.—Further Researches on the supposed Substitution of Zinc for Magnesium in Minerals.[1] By Edward T. Hardman, F.C.S., &c., Geological Survey of Ireland.

[Read, February 25, 1878.]

Some time ago, during the analysis of chalk from the county Tyrone, I noticed that the specimens examined contained traces of zinc, and I also found that metal in small quantity in the overlying basalts. It subsequently occurred to me that, owing to its marked relations in physical and chemical characters to magnesium, zinc might be expected to occur in rocks or minerals containing compounds of the latter metal. Accordingly, I made some analyses of such magnesium minerals as I had at hand, and the results, which fully equalled my expectations, were laid before this Academy, and printed in the *Proceedings* for 1874. Those analyses comprised some eight or ten rocks or minerals characterised by magnesian compounds. Since then, in the intervals of other chemical research, I have continued this investigation, and in nearly every instance I have obtained small quantities of zinc combined in these magnesian rocks or minerals, and also in a few cases in minerals of the metals belonging to the same isomorphous groups as zinc and magnesium—for instance, in iron pyrites, and in limestone, in which there was little or no magnesia. I give below a list of twenty different specimens from various places, in all of which zinc is unmistakeably present, and often in very appreciable quantity.

Method of Analysis.—In all but one or two cases the analysis was twofold. First, an examination with the blowpipe was made, and then if zinc was indicated, a complete analysis in the wet way. In many instances the blowpipe results were so strongly marked, and so unmistakeably showed the presence of zinc, that a wet analysis was really superfluous. But to put the matter beyond all question, it was performed on a sufficiently large quantity of the rock or mineral.

For details as to the analytical methods adopted, I shall only refer to my former Papers on this subject, where they are given fully. There is one point worth mentioning, however, in this connexion. It appears to be usually the impression that the only reliable blowpipe tests for zinc are the white incrustation, and the green colour imparted by nitrate of cobalt; and that it is too volatile to be reduced to the metallic state on charcoal. Such appears to be the idea on which are based the directions for its detection, in many books on Chemical Analysis, or special works on the Blowpipe, but it is an erroneous

[1] See "Analysis of Chalk, County Tyrone, with Note on the Occurrence of Zinc therein," *Journal Royal Geological Society of Ireland*, vol. iii., p. 159. Also *Geological Magazine*, vol. x., p. 434; and "On a supposed Substitution of Zinc for Magnesium in Minerals," *Proceedings Royal Irish Academy*, vol. i. Ser. 2 (Science), p. 534.

one, for with care the metal is easily reducible. With less than half a grain of mineral, containing a mere trace of zinc, fused on one of Griffin's reduction pastiles, I have obtained sufficient of the metal to apply the most characteristic wet tests, and such as could leave no doubt as to the nature of it; while with large capsules, and a properly managed reducing flame, the feat is perfectly easy with larger quantities.

The following list gives the principal specimens in which I have found zinc:—

(1). *Talc Schist* from the sea shore, Mullaghglass, county Galway,[2] containing large, well-defined hornblende crystals. The blowpipe analysis gave strong indications of zinc. This was confirmed by a wet analysis, which showed the presence of zinc in appreciable quantity. Small quantities of copper, silver, lead, and nickel were also present.

(2). *Hornblende.*—The crystals from the above also contained zinc.

(3). *Dark-green Serpentine* from N. slope of Croagh Patrick Mountain, county Mayo, contains considerable traces of zinc; also copper, and a small quantity of nickel, quite enough for estimation. This fact deserves particular notice, since it is the only serpentine in this country, as far as I am aware, in which nickel has yet been observed. Doubtless it is of not unfrequent occurrence in such rocks, but Dana's lists of analysis only mention a few localities, most of which are American.[3] It might be expected also to occur in magnesian rocks, its compounds being isomorphous with the corresponding ones of magnesium and zinc; and, in fact, I have often met with it in such rocks, but never in such large quantity as in this specimen.

(4). *Flesh-coloured Dolomite* from the carboniferous limestone of Ballyfoyle, near Kilkenny. The blowpipe showed zinc to be present, which was confirmed fully by a wet analysis. Small quantities of copper and lead were also present.

(5). *Dolomite* from Ballyfoyle, similar to above. Presence of zinc shown by blowpipe and wet analysis. In both these in small quantity for magnesian rocks.

(6). *Dolomite* from Clara, near Kilkenny, similar to the above; extremely friable, contains crystals of calcspar; blowpipe examination proved the presence of both zinc and lead. Two wet analyses confirmed this, and showed the zinc to exist in estimatable quantity.

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[2] For this and other Galway and Mayo specimens I am indebted to my colleague Mr. G. H. Kinahan, M. R. I. A. For several others, to my colleagues Mr. Nolan, M. R. I. A., and Mr. Henry.

[3] Since writing this I find it has been noticed in the black serpentine of the Lizard. See Rev. T. G. Bonney, M. A., and W. H. Hudleston, Esq., M. A., "On the Serpentine and Associated Rocks of the Lizard District," *Journal Geological Society of London*, 1877, p. 925. Mr. Kinahan informs me that nickeliferous pyrrhotite occurs in veins in the old beds of the Croagh Patrick district. The age of their veins is, however, not certain.

(7). *Very compact Crystalline Magnesian Limestone* from Tawnagh, Toormakeady, county Mayo. Associated with upper Silurian rocks and bedded igneous rocks. The blowpipe and subsequent wet analysis showed the presence of zinc in small quantity.

(8). *Hornblende Schist* from Inish-gloria Island, Belmullet, county Mayo, gave small traces of zinc.

(9). *Hornblende Rock* from Annagh Head, Belmullet. Blowpipe examination proved this to contain zinc in very appreciable quantity, confirmed by subsequent wet analysis. A little copper present.

(10). *Very pure Talc* from county Galway. The blowpipe showed considerable traces of zinc, and some of lead. Zinc very distinct.

(11). *Black Mica* from a vein in the summit of Liss-oughter, county Galway. The blowpipe gave the usual indications of zinc *very distinctly*. Quite a number of spangles of zinc were reduced. Wet analysis confirmed its presence. Traces of copper and lead were also observed.

(12). *Orthoclase Felspar* from a felstone porphyry, county Mayo. The blowpipe gave faint indications of zinc. On reduction, a few tiny spangles were obtained, which gave the usual zinc reactions. The very small quantity of zinc present is thoroughly consistent with the theory of its connexion with magnesium, since orthoclase contains usually a very trifling amount of that metal.

(13). *Hornblendic Epidotic Rock* containing numerous radiated nests of *Actinolite* or *Tremolite*, from Cannaver Island, Lough Corrib. This rock is described by Mr. Kinahan as passing into serpentine rocks.[4] The *actinolite* is almost infusible, and appears to be a highly magnesian variety. With the blowpipe it gave abundant indications of zinc. The mineral reduced with carbonate of soda yielded a large quantity of spangles of metal easily soluble with evolution of hydrogen, in dilute hydrochloric acid. A wet analysis fully confirmed this. Traces of copper and lead were also observed.

(14). *A Serpentine Rock* from N. W. slope of Croagh Patrick, county Mayo. In a compact base contains crystals of hornblende, and layers of fibrous serpentine. The fibrous serpentine, reduced with carbonate of soda, gave numerous spangles of zinc, which afforded the usual zincic reactions.

(15). *Chlorite* from a granite from Limehill, near Pomeroy, county Tyrone. Traces of zinc very distinct.

(16). *A dark graphitoidal steatitic Argillite* from county Mayo. Examined with blowpipe. Indications of zinc distinct.

(17). *Very pure greenish Steatite* from county Mayo. The blowpipe analysis of this yielded a large indication of zinc and nickel; also traces of lead. This specimen contained an estimatable quantity of nickel; and in order to be certain of the presence of zinc, which was rendered

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[4] Ex. Mem Sheet 95, *Geological Survey, Ireland*, pp. 13 and 33.

difficult by the presence of the former metal, no less than four distinct wet analyses from different portions of the mineral were made. In all of these both nickel and zinc were present, the former somewhat abundantly.

(18). *Talc Rock* from Crohy Head, county Donegal. From Geological Survey Collection. A white or cream-coloured rock. The blowpipe examination proved in this the presence of zinc, together with small traces of copper and lead. A proof experiment with another portion of the mineral, boiled in strong hydrochloric acid, showed the zinc to be present in appreciable quantity.

(19). *Iron Pyrites.* The last mineral contains numerous small crystals of iron pyrites. These, examined in the usual way, yielded zinc. As I have already remarked, ferrous iron belongs to the magnesium group.

(20). *Actinolite Rock* from Cannaver Island, Lough Corrib. Similar to No. 13. Blowpipe analysis proved this to contain zinc in the same quantity as in No. 13.

(21). *Serpentine* from Liss-oughter, county Galway. With the blowpipe a remarkably distinct indication of zinc. The mineral, reduced with carbonate of soda, yielded quite enough metal for identification. Besides zinc, nickel is also present in some quantity, and there are traces of silver and tin.

What I wish to urge upon your attention, as the result of these investigations, is the almost invariable occurrence of zinc in the minerals examined. I have already shown that the presence of zinc as an accessory component of minerals has been almost entirely neglected—in fact it is only mentioned where it occurs in considerable quantity, as in Franklinite or Automolite; and so uncommon is it looked on as an accessory, that the only augite in which its presence had been recorded before I had commenced this research was dignified with a special name—Jeffersonite.[5]

When a metal not usually occurring in rocks in any large quantity is recorded, it is usually because it exceptionally occurs so abundantly that its presence cannot well be overlooked; and it is only in such cases that zinc has been hitherto observed. It appears, however, that, like many other substances, it only requires to be sought after; and that its presence is not simply accidental, but the result of the invariable chemical laws of affinity and isomorphism; and I submit that zinc is as much to be regarded as an almost constant associate of the magnesium group as indium and osmium with platinum; niobium with tantalum; rhuthenium and rhodium with palladium, and so on.

In all the instances I have noted in this and my former Paper, the quantity of zinc is small; but this again is really in favour of my view. Had the metal occurred in large quantity in portions of the

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[5] Dana, *System of Mineralogy* (1873, p. 215).

rock, we should be entitled to consider its presence accidental; but its occurrence in small amount, and its being generally diffused in the rock or mineral, proves it to be truly a constituent.

A lode or thick deposit of zinc ore would be an accidental deposit; but it is from the infinitesimal quantities of this metal disseminated throughout rocks that workable accumulations are derived. As Bischof remarks, the minimum of a mineral in rocks becomes the maximum in lodes; and, although the small traces of zinc in the specimens given above may appear insignificant, it must be remembered that a knowledge of the fact of the diffusion of minute quantities of the metallic compounds through rocks leads to a correct notion of the formation of mineral veins, as otherwise we should be compelled to regard them as exotic productions, derived from unknown sources.

XXIV.—On the Negative Pedal of a Central Conic. By John C. Malet, M. A.

[Read, February 25, 1878.]

Abstract.

Having in some preliminary investigations proved a certain property of circular cubic curves which I require for the direct object of my Paper, I then investigate directly the principal properties of the first negative pedal of a central conic from any point. Many of these properties I show are also true for a more general class of curves, viz.: unicursal sextics with six cusps: thus for any such curve the following properties are true:—

(1). The six cusps lie on a conic.
(2). The six cuspidal tangents touch a conic.
(3). The eight tangents at the four double points touch a conic.
(4). The six points of contact of the three double tangents lie on a conic.

I prove, however, many less general properties of the curve I consider, which I believe are worth noticing—for example:—

"If we take the first negative pedal of a central conic from any point on either axis, then the six tangents to the curve from the cusps, but distinct from the cuspidal tangents, all touch the same conic."

Again:—

"The sixteen tangents at the eight double points of the negative pedals, with respect to the origin of the conics

$$ax^2 + by^2 + 2gx + 2fy + c = 0,$$

and

$$bx^2 + ay^2 + 2gx + 2fy - c = 0,$$

all touch the same conic."

The last part of my Paper is occupied with the consideration of a curve which is the locus of the centre of a variable circle, which cuts orthogonally a given circle and touches a given curve. From the equation of this locus I prove that we may at once deduce the equations of the following curves:—

(1). The negative pedal of the given curve.
(2). The parallel of the given curve.
(3). The negative pedal of the parallel of the given curve.
(4). The locus of the centre of a variable circle which touches the curve and a fixed circle.

I conclude by showing that we can form the equations of the parallel *et cetera* of a surface in an analogous manner.

XXV.—On the Extraction of Iodine and Bromine from Kelp. By Robert Galloway, F. C. S., Professor of Chemistry in the Royal College of Science for Ireland.

[Read, April 8, 1878.]

Having had, some time ago, facilities for becoming completely acquainted with the manufacturing processes followed for the extraction of iodine, bromine, and the potash salts from kelp, I devoted a considerable portion of time to the study of this branch of manufacturing industry. It is one of the manufactures which ought to flourish in Ireland, owing to the large quantity of the raw material (sea-weed) which can be obtained in this country. I am sorry to have to state that there is now no kelp factory in Ireland; the only buyers of Irish kelp at the present time are the Scotch manufacturers.

The description in works on Chemistry, of the processes followed for the extraction of the kelp products, are very meagre in a manufacturing point of view, especially as regards the extraction of the two most valuable substances, iodine and bromine, and these two substances are the most difficult to extract with manufacturing success. The descriptions state that such and such processes are followed; but important details are altogether omitted, as, for instance, the conditions most suitable for carrying out the processes successfully, and the different precautions which ought to be observed.

Iodine was at one time a monopoly. The iodine manufacturers combined together not to sell this substance under a certain price; which, like almost all other monopolies, had the effect of impeding rather than of promoting improvement in this branch of manufacture. The monopoly exists, I believe, no longer: new sources of supply of the substances I have termed kelp products—iodine from the mother liquors obtained in refining the nitrate of soda in Peru, bromine and potassic chloride from the salt beds in Prussia—have not only extinguished it, but have also rendered necessary the adoption of superior and more economical methods in the extraction of these substances from kelp, for the continuance of kelp being employed as a raw material.

Many methods have been proposed for the extraction of the two metalloids, iodine and bromine, from the ash of sea-weed; but the only one, as far as I am aware, which has been followed in the United Kingdom, at least up to a very recent period, is the one ascribed to Wollaston. By this method they are set free from the metals with which they are combined by the addition of sulphuric acid and manganese peroxide to the mother liquor which remains after the extraction (of course as far as it is practicable) of potassic sulphate and chloride, and what are termed the kelp salts, which are a mixture of sodic sulphate, carbonate, and chloride.

The sulphuric acid is added for a twofold purpose: a portion is required for the decomposition of the alkaline sulphides, sulphites, and hyposulphites, present in the mother liquor; the other portion, along with the manganese oxide, liberates the iodine and bromine from their combinations. When the sulphur, which is set free from

the decomposition of the hyposulphites, has completely deposited, the clear liquid is drawn off into the iodine still, and the manganese peroxide is then added to it.

When this process first came into operation, bromine had not been discovered in the ash of sea-weed; even the late Dr. Anderson, in his well-known and often quoted analyses of the ash of sea-weed, does not give it as a constituent. New analytical investigations of the ash of the various sea plants are wanted; the plants ought to be carefully freed, before incineration, from all adhering salt water, so that the quantities of chlorine, bromine, and iodine they naturally contain might be correctly ascertained. The investigation would lead, most probably, to the discovery that there are, properly speaking, *bromine* as well as iodine producing plants.

The three metalloids are each liberated from their metallic combinations by the manganese peroxide and sulphuric acid, but owing to their different degrees of affinity for metals—chlorine having the strongest, and iodine the weakest affinity—the latter is the first set free; but it requires the greatest care and attention to prevent some portion of the other two from being set free at the same time. If this occurs, they enter into union with one another, forming volatile compounds which affect the eyes, and have a very pungent odour. The liberation of the bromine or chlorine, or both, during the extraction of the iodine may occur, for instance, from the manganese oxide becoming unequally diffused in the liquid; they will also be liberated if the temperature of the liquid becomes too high; and it appears to me highly probable that the influence of *mass* will also cause their liberation, especially when the quantity of iodine becomes, by volatilization, much decreased in quantity. That they are liberated to some extent during the distillation of the iodine is at once perceived by those who visit the still during the distillation, and who are acquainted with the properties of these compounds. I may here observe that the still-man judges whether at least an undue proportion of the other two are volatilizing by the colour of the vapour; if it is of a brownish or whitish colour he is aware he is losing iodine. When the distillation is finished, and the still head removed, the vapour which escapes from the still has always a violet colour, and some iodine always remains in the liquid; for if the distillation were continued until all the iodine had volatilized, there would be evolved along with it in the last stages one or both of the other metalloids in somewhat large proportions; and consequently there would be a loss instead of a gain in iodine. These are some of the imperfections and difficulties of Wollaston's process.

The extraction of bromine follows the extraction of iodine, the same process being adopted, and similar precautions have to be observed.

It is evident such a process is unsuitable for the extraction of valuable substances like iodine and bromine, and it may also be observed that the liquid from which they have been volatilized has to be thrown away, on account of the difficulty of utilizing it, although

it contains a large quantity of potash salts and all the sulphuric acid employed in the extraction; the money value of which is estimated to be nearly one-half of the whole cost for extracting all the products from the kelp.

Chlorine is the agent, out of the many proposed as substitutes for the manganese oxide and sulphuric acid, which I would recommend, but under conditions somewhat different from those I have seen described; this difference in the conditions would render the process more exact, and better results in every respect would be obtained. The kelp solution I would render neutral by the addition of sulphuric acid before adding an aqueous solution of chlorine; and as I have found by investigation that the kelp solution contains clay, and as this substance tends to render the solution viscid and unfavourable for crystallization, I would, before evaporating to obtain the last crop of potassic chloride, nearly neutralize the liquid so as to get rid of it. Although a little more acid would be consumed than if it were all added in the ulterior stage, the disadvantage would be more than compensated by the larger crop of crystals of potassic chloride which would be obtained, and the greater concentration of the liquid. After the extraction of the last crop of potassic chloride, I would neutralize the liquid exactly, and then place it in a graduated vessel; I would then add to a small measured portion of it some bisulphide of carbon, and finally some chlorine water from a graduated vessel, until the violet colour just disappeared. This is a process frequently employed for the estimation of iodine, and occupies only a minute or two. Having ascertained the exact quantity of chlorine water which decolourizes the iodine—that is, converts it into pentachloride of iodine—it would only remain to add to the larger measured quantity of the liquid containing the iodine one-sixth of the relative quantity of the chlorine water which was required on the smaller scale. The small portion of iodine which would remain dissolved in the liquid, owing to its slight solubility in water, I would remove either by bisulphide of carbon or benzol. After the removal of the iodine, I would treat the liquid with chlorine water, with similar precautions for the removal of the bromine; but as the compound of chlorine and bromine is a monochloride, one-half, and not one-sixth, as in the case of the iodine, of the relative quantity of chlorine water would have to be added to the larger measured portion of the liquid.

If, in any case, it should be found desirable not to precipitate the entire portion of the iodine and bromine with chlorine water, on account of rendering the liquid too dilute, a portion might first be precipitated by chlorine gas, and the remainder by means of chlorine water in the way I have described.

This method would not only be speedy but exact, for it would be the conversion of a quantitative analytical operation into a manufacturing process. After the removal of the bromine, the alkaline salts which remained in solution could be easily recovered.

It would be necessary to sublime the precipitated iodine.

XXVI.—On a New Chemical Test for Carbolic Acid, and its Useful Applications. By Edmund W. Davy, A. M., M. D., Professor of Forensic Medicine, Royal College of Surgeons, Ireland.

[Read, May 13, 1878.]

I had the honour, a short time ago, of bringing under the notice of the Academy, and of publishing in these *Proceedings*,[1] a new and exceedingly delicate chemical test for alcohol which I had at the time discovered; and I pointed out some practical applications which might be made of that test.

I subsequently directed attention to some further useful objects which may be attained by the employment of that alcoholic test, which latter have appeared in the *London Pharmaceutical Journal* for last year. I have recently discovered that the reagent which I employed for the detection of alcohol in the test referred to, viz., a solution of molybdic acid or molybdic anhydride in strong sulphuric acid, is a very delicate test likewise for carbolic, or as it is otherwise termed, phenic acid, a substance which is now one of considerable industrial importance, admitting as it does of so many useful applications, and one for which it is desirable to have a ready and at the same time a delicate test, for the detection of its presence under different circumstances. I have observed that when a drop or two of a dilute aqueous solution of carbolic acid is brought in contact with a few drops of the molybdic solution stated, there is immediately produced a light-yellow or yellowish-brown tint, which, passing to a maroon or reddish-brown, soon develops a beautiful purple colouration, which latter remains without further change for a considerable time. I should here observe that the application of a gentle heat will hasten the development of the purple reaction, though it will take place, but more slowly, at the ordinary temperature; and it is the production of this purple under the circumstances stated that constitutes the test for carbolic acid. The molybdic solution which I have chiefly used for this purpose is similar to the one I have employed for the detection of alcohol, and is made by dissolving, with the assistance of a gentle heat, one part of molybdic acid in ten parts by weight of pure and concentrated sulphuric acid. But the exact amount of molybdic acid dissolved appears to be a matter of indifference, as I have used other proportions with success, and in some recent experiments I found that a solution where there was only one part of molybdic acid in a hundred parts of sulphuric acid acted very well.

The mode of using this reagent is simply to add three or four drops of it to one or two of the liquid under examination, placed on any white porcelain or delf surface, when the effects already noticed will be produced, if carbolic acid is present. In carrying out this test, it will, however, be found the most convenient to use a small white porce-

[1] *Proceedings*, Second Series, vol. ii., Science, p. 579.

lain capsule, furnished with a handle, which will admit of the application of heat when it may be desirable to hasten the reaction by that agent.

This test is one of great delicacy, for I have found that one small drop of an aqueous solution of carbolic acid, containing a thousandth part of its weight of that acid, and only absolutely about the one-seventy-thousandth part of a grain, when mixed with three or four drops of the molybdic solution, produced immediately the yellowish-brown effect, which, after a few minutes, passed into a very distinct and beautiful purple colouration, and this colour remained quite perceptible on the fourth day afterwards, though it had each day become fainter from exposure to the air, and its consequent absorption of moisture. But this is not the limit of its delicacy, for I have detected by its means the carbolic acid in one drop of an aqueous solution five times more dilute, or where it contained the one-five-thousandth part of its weight of that acid, and in which there was only about the one-three-hundred-and-fifty-thousandth part of a grain present.

For the success of this test, it is necessary to attend to a few particulars, one of the most important being, that only a drop or two of the liquid under examination should be employed, for if much more be used the reagent will be diluted too much, and the characteristic reaction will not take place: for so great an effect has water on it, that even when the purple colouration is fully developed, the addition of that substance will cause either the colouration to disappear almost entirely, if the quantity of carbolic acid present be exceedingly minute, or if more abundant it first changes the purple to red, and then into a light reddish-brown, which becomes more and more faint on further dilution; but the addition of a few drops of the test solution, or even of strong sulphuric acid, again reproduces the purple, though of course fainter in its colour in proportion to the previous degree of dilution; thus showing that the mixture must be very strongly acid for the production and continuance of this purple effect. Another point to bear in mind is this, that when carbolic acid itself, and not an aqueous solution of it, is acted on by the molybdic reagent, a dark olive, quickly changing to a very deep blue, will be produced, but not the purple colouration; a cold saturated aqueous solution, however, of carbolic acid when so treated will yield the purple reaction; but even here there will be a tendency to develop the olive or blue effect, especially where the reagent employed contains a large proportion of molybdic acid; and I may observe that weaker solutions of carbolic acid give more satisfactory results, as the action appears to be too energetic when the acid itself or very strong solutions are employed.

The last precaution I wish to direct attention to, for the successful performance of the test, is this, that in applying heat to hasten the reaction, it should be limited to a gentle heat that the hand can bear when applied to the bottom of the capsule, this being about from 120° to 130° F., which is quite sufficient for this purpose, besides not exercising any destructive effect on the purple reaction; for I may observe that if the heat be raised even to 212° F., and con-

tinued for some time, the purple colouration will be destroyed and a blue produced; moreover, where organic matters are present along with the carbolic acid, many of them will likewise, when heated with the molybdic reagent to that latter temperature, or even much below it, develop a deep blue colour, which would mask more or less completely the purple effect of the carbolic acid. Consequently it is better in most cases to let the test act on the liquid at the ordinary temperature, though the reaction may be somewhat slower in developing itself.

I have made a number of comparative experiments with this test, and with the principal ones hitherto employed for the detection of carbolic acid, and I find, in point of delicacy, it seems only to be surpassed by the bromine test of Dr. Landolt, which depends on the circumstance that when an aqueous solution of bromine is brought in contact with carbolic acid, there is immediately formed the tribromophenol ($C_6H_3Br_3O$), a sparingly soluble white substance. But that test could not be successfully employed, at least immediately, in many cases, where the test just described might be still available, as for example, in the case of different organic mixtures, where the presence of the tribromophenol formed would be concealed. It possesses likewise the great advantage of being apparently not interfered with, to any extent, by the presence of organic substances which mask or prevent the reactions of many of the other tests.

As to what is the exact nature or composition of the purple compound which is formed in carrying out the test, I have not yet been able to determine, owing to the difficulty of isolating it, or of obtaining it in a condition suitable for analysis; but I am inclined to think that it is not so much an oxidation product of carbolic acid as a deoxidation one of molybdic acid, and that it is a combination of one of the oxides of molybdenum, containing perhaps more oxygen than the blue compound which is formed where the molybdic reagent acts on alcohol and on some other substances; and one circumstance amongst others which seems to support this view is this, that I have failed to obtain by the action of other oxidizing agents on carbolic acid a similar purple reaction.

Be this however as it may, I have satisfied myself that the purple compound formed in my test is a totally different substance from the red or crimson dye termed coralline, which is obtained by the united action of oxalic and sulphuric acids on carbolic acid, and is now largely used as a dyeing material; for the red colour of the latter substance is not affected by the caustic alkalies, and strong sulphuric acid changes it to a reddish yellow; whereas the purple developed in the new test is changed to green by caustic alkalies, and the purple again restored by strong sulphuric acid. I am, however, still engaged in this inquiry, and hope to be able yet to determine the exact nature of this purple compound, and of the changes which occur in this new reaction.

I shall now briefly notice some of the useful applications which may be made of this test. It is well known that carbolic acid is a

powerful poison, and many instances are now on record where it has been the cause of death, such being generally either cases of suicide, or those where it has been accidentally taken by mistake for some other substance; as its odour and taste would render its administration, at least to an adult, by the assassin for the criminal destruction of life, a matter of some difficulty. The occurrence, however, from time to time of the cases referred to obviously renders it very desirable to be able readily to detect the presence of carbolic acid where it has been so used, either in the articles of food, drink, or medicine which have been taken, or in the ejecta or contents of the stomach; and this test affords a very easy and ready means of so doing, and of confirming the indications of other tests. According to my observations it will detect the presence of carbolic acid in different complex organic mixtures, even where the odour of that substance may be quite imperceptible; and I may observe, that the test of odour has hitherto been regarded as the most delicate for carbolic acid in such cases.

The great advantage this test possesses, especially for such applications, is this, that it does not appear to be much affected or interfered with, as already stated, by the presence of a number of organic substances which are likely to be present in such cases. Thus, as regards different articles of food—I have readily detected, by means of this test, the presence of carbolic acid when a small quantity of its aqueous solution had been added to the following articles, viz.: tea and coffee mixed with sugar and milk, porter,[2] ale, wine, a solution of Liebig's extract of meat, and albumen; also where it had been added to blood, olive oil, gum, and soap—the very diverse substances in the articles mentioned not preventing the indications of the test.

It will also afford a ready means of detecting the elimination of carbolic acid in the urine, when that substance has been taken internally, for the compounds present in human urine naturally do not appear to affect to any extent this test. I may also observe, that with it I was at once able to detect the presence of carbolic acid naturally occurring in the urine of a cow, without any previous treatment of that secretion, and thus confirm the correctness of the statement as to the occurrence of that acid as a normal substance in the urinary secretion of that animal. This ready means of discovering carbolic acid in different animal fluids where it may exist will render this test useful to the physiologist and physician.

[2] As alcohol acts on the molybdic solution producing an intense blue colouration, the presence of that substance, at least in any quantity, would mask more or less completely the reaction of carbolic acid. In examining, therefore, alcoholic liquors for that acid, it is better to submit them to distillation to separate the alcohol, and then to test the later portions of the distillate or the residue for carbolic acid; or what answers even still better in such cases is, to render the liquid alkaline by the addition of either caustic potash or soda, to combine with and fix the carbolic acid, and then distil; and when all the spirit has been removed, to add diluted sulphuric acid to slight acid reaction to liberate the carbolic acid, and after this distil again, when that acid will come over unmixed with any spirit, and give its characteristic reaction.

Another useful application of this test is, that it affords a very ready means of distinguishing creasote from carbolic acid, which is a matter of some commercial importance, much of what is sold as creasote being, as is well known to chemists and those in the drug trade, little else than carbolic acid; for these two substances, though obtained from different sources—true creasote being procured from the distillation of wood tar, whilst carbolic acid is got from that of coal tar—and though they differ likewise from each other in chemical composition, still so closely resemble each other in several of their properties, that the cheaper substance, impure carbolic acid, is in whole or in part frequently sold to the public for the dearer article creasote. If, however, we take a drop or two of each, and agitate them well with about a quarter of a fluid ounce of distilled water, and, having filtered the liquid, test a drop or two with the molybdic solution as already described, we will get in the case of pure creasote only a brown or reddish-brown reaction, which on standing or warming slightly becomes fainter, passing to a light-yellowish brown: whereas in the case of carbolic acid the brown passing to a maroon soon develops a more or less intense purple colour. This treatment will be sufficient to distinguish creasote from carbolic acid, and also to detect the presence of that acid in creasote, where it occurs in considerable proportion; for if, on the addition of the molybdic test solution, the mixture, instead of fading away to a light-yellowish brown on standing a short time, or on gently heating, passes to a reddish brown or to a maroon, it is an indication that carbolic acid is present. But I have found that the following very simple proceeding gave more satisfactory results, especially where small quantities of carbolic acid had been added to a large proportion of creasote. From five to ten drops of the liquid under examination are taken, and agitated briskly with about half an ounce of distilled water for a few minutes, so as to dissolve out the carbolic acid; the mixture is then filtered, and the filtrate is put into a little flask furnished with a close-fitting cork, through which passes a small glass tube about ten or twelve inches long, and bent above the cork at a little more than a right angle. The contents of the flask are then heated, and, when the liquid boils, the first portions which distil over will be found to present a more or less turbid appearance as they pass down the tube, from their containing minute globules of creasote; and a drop or two having been collected and tested with the molybdic reagent will give only the brown reaction of creasote: but by continuing the boiling, that substance will be more or less completely expelled, and then it will be found that a drop or two of the later portions of the liquid which distil over will give the purple reaction of carbolic acid. I may here observe that as it is only a drop or two of the distillate which is required each time for testing, it is not necessary to use any condensing arrangement, for the vapour passing through the tube itself is cooled sufficiently to furnish the small quantity required for each trial; but when it is desirable to collect in larger quantities the

different portions of the distillation, a very small Liebig's condenser, in which the delivery tube can be inserted, will be found the most convenient arrangement to employ. In this way, by distillation, I was enabled to detect the presence of carbolic acid in creasote, where I had mixed only one part of the former with a hundred parts of the latter, which would be more than sufficiently delicate for any case likely to occur in commerce; for where such adulteration was practised, it is probable that a much larger proportion of carbolic acid would be used, to render the fraud sufficiently remunerative. In the same way, I have readily succeeded in detecting the presence of carbolic acid in oil of cloves, where I had purposely added a small proportion of that acid, as it is stated that this very objectionable fraud is occasionally practised, of adulterating the essential oil of cloves with carbolic acid.

The few applications that I have referred to are, I should trust, sufficient to indicate the practical utility of this test; which, being at the same time so simple and easily performed, will, I have no doubt, be found useful for the objects stated, as well as for others to which it may be applied.

XXVII.—On Hullite, a hitherto undescribed Mineral; a Hydrous Silicate of peculiar composition, from Carnmoney Hill, Co. Antrim, with Analysis. By Edward T. Hardman, F.C.S., H.M. Geological Survey. With Notes on the Microscopical Appearances, by Professor Hull, F.R.S.

[Read, June 24, 1878.]

Part I.

Happening to visit Carnmoney Hill, near Belfast, during the Meeting of the British Association in 1874, I was much struck with the abundance in the basalt of a mineral which I had never before noticed in any of the basalts of the north of Ireland, and which I had reason to believe then, and still consider to be, somewhat new to Irish mineralogists, in so far that its composition and physical characters have not yet been described. It may have been observed before, but there is no description, at all agreeing with its characteristics, published.

The basalt in which this mineral occurs forms the old neck of a Miocene volcano. It is massively columnar, the columnar structure being, however, horizontal, not vertical, as is usually seen; but in all respects similar to what may be observed in large dykes or other masses of intrusive basalt. The rock itself is a rather coarse-grained dolerite; extremely vesicular and amygdaloidal, possesses a very high density, and is magnetic, affecting the needle very strongly—zeolites are not abundant, but the cavities are filled, or in some places only coated, with a peculiar black mineral which is the subject of the present notice.

In some cases this mineral entirely fills up the cavities, and throughout the rock it appears in great profusion; but in many places where the amygdaloids are only partially coated with it, the remaining space is filled with calcite—and occasionally apparently arragonite—for sometimes the crystals have a radiated structure which resembles that of a zeolite.

The black mineral from this locality has, I believe, never been hitherto described or analysed. On examining the maps of the Geological Survey I find the basalt is noted by the late Mr. Du Noyer as "black basalt, highly crystalline; cellular cavities lined with pitchstone," for which he evidently mistook this mineral. And in the Geological Survey collections in the Museum of the College of Science, Dublin, specimens from this place are labelled "Vesicular basalt, with obsidian." However, the peculiar softness of the mineral precludes this idea at once. There are two minerals to which it bears a distant resemblance. In physical characters it somewhat agrees with the chlorophæite of Macculloch, so far as colour, specific gravity, and hardness. But its chemical properties are totally different, as will be seen further on—that is, if we can rely upon the analyses of

that mineral by Macculloch and Forchammer, which give very extraordinary results. The presence of so called chlorophæite has been noted by Portlock[1] as occurring in the basalt of Down Hill (p. 227); Magilligan—abundantly in several beds exposed in the section there (p. 152–3), and at Carrick-a-rede, where the mineral imparts a porphyritic appearance to the rock (also at Craigahulliar, p. 154), and he mentions localities as Crosseagh and south Ballylagan where the trap, wanting the imbedded chlorophæite, has cavities occasionally lined with obsidian (p. 155)—this he mentions as occurring at the Giants' Causeway. Now it seems improbable that a highly acidic mineral such as obsidian would be found in basalt; and I am inclined to suppose that Portlock, as Mr. Du Noyer did afterwards, mistook the Carnmoney Hill mineral for obsidian.

Whether this Carnmoney Hill mineral is the same as that which Portlock calls chlorophæite I cannot say, as I have not seen specimens from the localities he names. But it is not at all clear that Portlock's so called chlorophæite is that of Macculloch, since analyses of it are wanting. If it be the same mineral as that I have examined, the composition is entirely different.

In chemical composition the mineral approaches more nearly to delessite. However, there are still very important differences, as will be seen on comparison. Delessite contains considerably less silica, more alumina, and more protoxides—lime especially being abundant. Again, the physical characters do not agree,—delessite is harder; its gravity is nearly $\frac{2}{3}$ more, its colour and streak different,—so that on the whole we must regard this mineral as a new one, although possibly belonging to the ferrugenous chlorite group.

Method of Analysis.—Separation of the mineral. This is so important a point that it may be well to devote a few lines to the description of the manner adopted. Although the mineral occurs most abundantly in very small nodules, it was found to be a most tedious process to extract sufficient of it even for a qualitative analysis. One method was to crush the rock—extract as much of the matrix as possible by means of a strong magnet, the small particles of magnetite, or perhaps native iron disseminated throughout it, rendering this possible, and collecting the mineral bit by bit with a forceps from the felspar and augite which remained behind. This, however, promised to be an endless proceeding—but I fortunately at the time happened to meet with a notice of the use of Sonstadt's solution for that purpose;[2] this I tried, and it succeeded so admirably that, although I have already noticed the result elsewhere,[3] a short description of the process may not be out of place here, as it is a matter that cannot be too well known to mineralogists.

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[1] *Geological Report on Londonderry, Antrim, &c.*

[2] Prof. Church, *English Mechanic*, January, 1878.

[3] "On the applicability of Sonstadt's solution to the separation of minerals for chemical analyses."—*Chemical News*, April, 1878.

Sonstadt's solution is a solution of mercuric iodide (or red iodide) in potassic iodide—the liquid being concentrated by adding, alternately, the mercuric and the potassic iodides until no more of either is taken up. Carefully proceeding in this way, a clear liquid can be obtained, having a specific gravity of a little over 3·00, according to Sonstadt and Church. It is clear that any mineral of less specific gravity than 3· floats on such a liquid, while any of higher gravity of course will sink; by diluting the liquid we can obtain a range of solutions capable of separating any minerals between 1·0 and 3·0 s. g. The Carnmoney mineral being of low specific gravity, a solution of about 2·0 was sufficient. The rock being crushed up and sifted, to get rid of small dust, which would have rendered the result less palpable, was thrown into a dish filled with the solution. Everything but the new mineral sank to the bottom. The latter was then skimmed off, and immediately washed with distilled water to which a little potassic iodide had been added, to dissolve any red iodide which would otherwise be thrown down, and finally washed with distilled water. When a sufficient quantity of the mineral had been thus collected it was again treated in the same way, and thus was cleared of a few particles of augite, &c., which had been caught up in the first floatation.

In this way about 3 grammes of the mineral were obtained, perfectly free from admixture, and quite sufficient to yield exact analytical results.

The analysis was conducted in the usual way, by the fusion of the powdered mineral with the alkaline carbonates. Although it appears to be nearly altogether decomposed by boiling (when powdered) in strong hydrochloric acid, the fusion process seems to be the most complete method, and is the shortest in the end; because, if boiling with acid is depended on, the insoluble residue will be found almost invariably to contain undecomposed silicates, giving an excess in the amount of silica.

The ferrous iron was determined according to Early's method, namely, by decomposing the mineral with hydrofluoric acid, and estimating the ferrous iron as quickly as possible by means of a standard solution of bichromate of potassium.

As it was not easy to obtain enough of the mineral to enable its specific gravity to be taken in the ordinary way, its gravity was determined in a somewhat novel way. It floats on, and is hardly affected, even after some months, by strong sulphuric acid of the usual density, viz., 1·84. Dilute sulphuric acid, of the density of the mineral, was prepared, and the specific gravity determined by means of a delicate hydrometer;[1] the density by this means was found to be only 1·76, so

[1] Sonstadt's solution might have been used, but sulphuric acid was found to be more convenient at the time.

The analysis was performed by me in the Laboratory of the Royal College of Science in Dublin, by permission of Prof. Galloway.

that the mineral is the lightest silicate known of, almost. This is very remarkable in a mineral containing such a very large percentage of iron, the peroxide amounting to 20·720 per cent.

Physical characters.—Colour, velvet black. Hardness, about 2, brittle; lustre, waxy but dull; streak, olive brown; Blow-pipe with difficulty fusible at edges to a black glass, which in some specimens is magnetic. Very slightly affected by strong HCl or H_2SO_4 when in the mass, but decomposed by the former when boiled in it in powder. Occurs filling amygdaloidal cavities in the basalt of Carnmoney Hill, near Belfast; Shane's Castle, Lough Neagh[1]; &c.

Chemical Composition and Formula.

I shall compare my analysis of this mineral with analysis of delessite and chlorophæite.

	Hullite.	Delessite.[2]	Chlorophæite.[3]
Silica . . . (SiO_2), .	39·437	31·07	33·30
Alumina . . (Al_2O_3), .	10·350	15·47	—
Peroxide of iron . (Fe_2O_3), .	20·720	17·54	—
Protoxide of iron . (FeO), .	3·699	4·07	26·70
Protoxide of manganese (MnO), .	Trace.	—	—
Lime . . . (CaO), .	4·484	19·14	—
Magnesia . . (MgO), .	7·474	0·46	—
Water . . . (H_2O), .	13·618	11·55	40·00
Carbonic acid . (CO_2), .	Trace.	—	—
	99·782	100·00	100·00
Formula	$[CaMgFe'']_3[Al''Fe''']_4Si_6O_{21} + 7H_2O$	—	$FeSiO_3 + 6H_2O$
Sp. gr., ...	1·76	2·89	2·02

Like other ferrugenous chlorites (as delessite), to which group this mineral appears in many respects to be allied, it is extremely difficult to express its composition by a chemical formula. In the first place, there is always some degree of alteration, which has changed the characters of the mineral; and besides, it is difficult to say whether these minerals are true silicates or combinations of silicates with aluminates. With regard to the last, it would be very difficult to decide

[1] A specimen of basalt from this locality containing very large cavities filled with this mineral is to be seen in the Museum of the College of Science, Dublin, as in the specimen mentioned, p. 161; the mineral is called obsidian.

[2] Dana's *System of Mineralogy*, 1874, p. 497.

[3] *Ib.*, p. 410. Also *Western Isles of Scotland*, &c. John Macculloch, M.D., p. 505.

one way or the other in the present case, and I would prefer to content myself with calculating a formula on the supposition that that mineral is only a silicate. However, the above analysis does not give a reasonable formula in its entirety. Calculated as it stands, it gives

$$M''_3\ M'''_4\ Si_6O_{21} + 7H_2O,$$

which fails to agree with any type of silicate I know of.

If, however, we subtract one molecule of peroxide, and suppose it to exist as a hydrate, and not combined, we get

$$(M'_3\ M''_2'\ Si_6O_{18}) + H_6\ M'''_2O_6 + 4H_2O,$$

the first member of which is a condensed meta-silicate on the type

$$H_{12}\ Si_6O_{18}$$

which would bring it sufficiently near the type of talcose and chloritic minerals. However, the general constitution, even allowing for this, is entirely different. Then again, we may suppose the excess of peroxide, as in the above, to act the part of an acid, an aluminate, or a ferrate, which is not improbable, and we thus get a formula not unlike that which has been proposed for ripidolite, but the silicate belonging to a different condensed meta-silicic series, viz.,

$$[M''_3\ M'''_2O_6 + M'''_2H_6\ Si_6O_{18} + 4H_2O],$$

a part of the water in this case being basic, as I have but little doubt it is, acting in fact as a protoxide.

It is extremely probable that the last formula gives a fair representation of the molecular composition of this new mineral.

I should wish to draw attention to one or two remarkable points about this mineral. 1° the very large percentage of iron it contains, and the small quantity of magnesia, although it is extremely refractory before the blow-pipe; and 2° its very low specific gravity, notwithstanding the quantity of iron it contains. The last circumstance is, I think, due to the very large percentage of water.

With regard to its claims to be an original mineral, and not simply a product of alteration, I would like to point out one or two strong evidences. The mineral occurs coating or filling ordinary amygdaloidal cavities in the basalt. It is clearly a product of infiltration into these cavities, and not an alteration of a previous mineral, because the walls of the cavities are quite distinct from the mineral. Were it a product of alteration, it might be expected to merge into the rock itself, or such minerals as might be altered to such a composition, such as olivine or augite; but this is not the case, the olivine and the augite are quite distinct from it. Under the microscope the mineral may be observed to fill up the cavities previously left in the rock; and crystals of

augite, felspar, and olivine may be seen to penetrate it in such a way as to leave no doubt that the Carnmoney mineral has been deposited in those spaces.[1]

Under these circumstances I consider it to be an original (but secondary) mineral, and believe it to be a new variety of the chloritic group, and a well-marked one. I therefore propose to give this Irish variety a distinguishing name.

Macculloch, in his description of the mineral chlorophæite, apologises for giving it a new name, saying that though it may afterwards turn out a variety only, its characteristics are strongly marked; and that the best chance of its obtaining future investigation will be derived by giving it a conspicuous place in the list of minerals. On the same grounds I venture to name the present mineral as a new species. Since distinctness of colour and hardness may vary in different specimens, and therefore mislead—and there is no earthly use in commemorating a single locality when the mineral may hereafter be found in hundreds of places—I submit that the best name would be that of an individual. I propose to name this species or variety Hullite, after Professor Hull; first because it has been analysed and described during his directorate of the Geological Survey of Ireland; and last, but not least, in commemoration of the valuable work he has done in the elucidation of the microscopic mineralogy of the rocks of Ireland, more especially that of the basalts.

In order to set at rest any question as to the mineral being an alteration product, Professor Hull, at my request, had some slices of the rock made, and the microscopic examination of them fully bears out my previous remarks, viz., that the mineral is perfectly distinct from, and does not merge into any part of, the basalt.

Part II.—On the Microscopical Structure of the Olivine Basalt of Carnmoney Hill, Co. Antrim. By Professor E. Hull, M. A., F. R. S.

The rock occurs as a dark crystalline mass, with columnar structure, filling the neck of an old volcanic vent of the Miocene age. (*See* Geology of the Country around Antrim, *Mem. Geol. Survey*, Sheet 21, p. 30). With the lens it is seen to consist of black glistering crystals of augite, set in a paste consisting of a light-coloured waxy felspar (plagioclase), and large and small grains of an opaque, black, dense mineral, with smooth, somewhat conchoidal, fracture, and brown streak. This unknown mineral is that to which Mr. Hardman has applied the name "Hullite," and the chemical composition of which he has determined. The olivine, though seen to be remarkably abundant

[1] See Prof. Hull's remarks further on.

under the microscope, is scarcely to be identified without the aid of a high magnifying power.

Microscopical appearance.—Under the microscope, and with a low power (25 diameters), the slice is seen to consist of light brown augite, without crystalline form, in which are imbedded short prisms of plagioclase, imperfect crystals of olivine, and a very few grains of magnetite. But the most abundant mineral is that now for the first time described by Mr. Hardman. It is of a dark umber brown colour, almost opaque, except at the edges, and it forms not only individual masses, but permeates the whole rock, filling the interstices, and enclosing the other minerals. In one instance, where it has apparently filled in a cell in the rock, the central portion is vacant; but it often forms considerable masses. As it does not polarize, it cannot be considered as in a crystalline molecular condition; and in its distribution, and relation to the other minerals, it assumes very much the character of amorphous chlorite. Like chlorite, also, it has every appearance of being a secondary mineral, formed after the consolidation of the rock, and with a high power shows a stalagmitic or chalcedonic structure, with wavy bands.

One of the most interesting circumstances regarding this rock is the abundance of olivine in its unaltered condition. In no other instance, amongst the basalts and dolerites of Antrim which I have examined, have I found it so abundant, and in its original state olivine, as is well known, is a mineral very liable to decomposition, and generally it has been completely removed, the outer form only being preserved. In the case, however, of the basalt of Carnmoney Hill, it is as abundant and as fresh as in the lavas of Vesuvius. This can be determined by the aid of the polariscope, by means of which the crystalline grains of olivine are separated out from the augite with which it might otherwise be confounded; but under polarized light, not only may the outline of the crystalline forms be recognised, but the mineral affords (on rotating the analyzer) the well-known alternation of colours, from ruby red to sap green, characteristic of this mineral. On the other hand, the colours of the augite are blue, grey, light pink, and yellow. The crystalline forms of the olivine are only imperfectly developed. The crystals of plagioclase—probably labradorite felspar—are well and sharply defined, and seem to have crystallized out before those of augite and olivine. With the polariscope they show the usual parallel-banded structure, varying with the angle of the analyzer.

From the remarkably fresh appearance of the olivine one might infer that this rock was comparatively recent, did we not know, from physical considerations, that it must be older than the Glacial and Pliocene periods.

XXVIII.—Further Observations on Pyrrol and its Derivatives.

By Chichester A. Bell, M.B., University Dublin.

[Read, June 24, 1878].

Synthesis of Pyrrol.

Several attempts which I have made to effect the synthesis of pyrrol have not been successful. The following experiment is chiefly of interest as suggesting a process by which bases of similar constitution are likely to be obtained artificially. When vapours of diethylamine $(C_2H_5)_2$ HN, are passed through a heated tube packed with recently-ignited pumice, they experience but little change if the temperature be much below that of redness. On the other hand, a good red heat is sufficient to decompose the base into a variety of products, amongst which ethylene, free hydrogen, cyanogen, and hydrocyanic acid, are easily recognised. If the tube be of sufficient length, the current of vapour not too rapid, and the temperature that of *incipient* redness, a liquid is obtained containing, besides much diethylamine, a considerable quantity of pyrrol. The change probably consists in a direct separation of hydrogen, thus—

$$\begin{matrix} CH_3-CH_2 \\ CH_3-CH_2 \end{matrix}\!\!>\!NH = \begin{matrix} HC=C \\ | \quad | \\ HC=C \end{matrix}\!\!>\!NH + 3H_2$$

I have not in this way prepared any large quantity of the base, but in all cases have estimated the product by the rapidity and intensity with which the vapours issuing from the tube exhibited the fir-wood reaction, the amount of precipitate yielded by the acidified distillate with mercuric chloride, stannous chloride, etc., and by the quantity of pyrrol-red obtained by boiling the liquid in the receiver with strong hydrochloric acid.

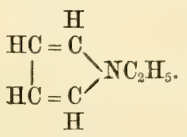
I think it not unlikely that the conversion of diethylamine into pyrrol may be effected in a more simple way.

On the so-called ethyl-pyrrol of Lubawin.

In my previous communication on this subject (these Proceedings, 2nd Series, vol. III., Science, page 33), I described a series of bases derived from pyrrol by the substitution of various alcoholic radicles for one atom of hydrogen. One of these, namely ethyl-pyrrol, $C_4H_4N(C_2H_5)$, differed widely in its properties from the similar base pre-

viously described by Lubawin.[1] According to this chemist, when iodide of ethyl acts upon potassium-pyrrol C_4H_4NK, substitution of the group C_2H_5 for potassium takes place, a body of the composition $C_6H_9N = C_4H_4N(C_2H_5)$ being formed. This base was said to have a turpentine-like odour, to boil between 155° and 175°C., and to turn brown rapidly on exposure to air. The metal potassium acts with great vigour upon pyrrol, expelling hydrogen and producing potassium-pyrrol; but upon ethyl-pyrrol from mucate of ethylamine it has little or no action. It would be contrary to analogy to suppose that in Lubawin's base the ethyl-group does not occupy the position of the potassium in potassium-pyrrol, and it was hence difficult to resist the conclusion that the bases prepared from potassium-pyrrol and from ethylammonium mucate must be identical. On repeating Lubawin's experiment I have found this to be the case. Potassium-pyrrol is most easily prepared in a state of purity by adding to pyrrol, contained in a flask with inverted condenser through which a stream of dry hydrogen is passed, rather less than the calculated quantity of bright metallic potassium. The action is violent at first, and must be moderated by the application of cold; towards the close it must be assisted by a gentle heat. The contents of the flask are finally heated to fusion, allowed to cool, the flask broken, and the solid mass dropped into a mortar containing anhydrous ether. It is then quickly powdered, the ether (which removes unaltered pyrrol) quickly poured off, and the powder again transferred to a flask provided with an inverted condenser. It is then covered with rather more than the theoretical quantity of ethyl iodide, and the mixture boiled for a couple of hours, a chloride of calcium tube being placed in connexion with the upper end of the condenser so as to prevent ingress of moisture. Towards the close of the boiling, a not inconsiderable amount of ammonia is evolved, evidently due to secondary decompositions. On fractionally distilling the contents of the flask, a very large quantity of *ethyl-pyrrol* is obtained, boiling at 131°C., and having all the other properties of the base from ethylammonium mucate. Above 131°C. a quantity of secondary products of inconstant boiling-point comes over, the thermometer rising to 180°. It is this mixture that Lubawin evidently mistook for ethyl-pyrrol, no doubt regarding the principal product of the reaction as unaltered pyrrol, from which indeed it differs but little in odour or boiling-point. (Pyrrol boils at 133°C.)

It is thus clear that only one ethyl derivative of pyrrol is yet known, no doubt having the constitution—



[1] "Zeitschrift für Chemie," [2] v. 399.

Condensation-products of Ethyl-pyrrol.

In my former paper I mentioned that ethyl-pyrrol may be boiled for some time with strong hydrochloric acid without experiencing any change, in this respect differing from pyrrol. If the boiling is continued for a sufficiently long time, this is not the case. Even when dilute acid is used, the base gradually dissolves, forming a deep-red solution which is not rendered turbid by the addition of water. This solution contains the hydrochlorate of a new base, or perhaps salts of several new bases. The product is obtained by precipitating the acid solution with ammonia in excess. On drying the precipitate *in vacuo*, or at a gentle heat, it is obtained as an amorphous powder, which is nearly insoluble in water, but is readily taken up by alcohol or ether. Its colour varies from pale brown to black, accordingly as it has been prepared with dilute or with strong acid. Heated on the water bath it constantly loses weight, giving off a peculiar odour. Analyses showed it to be of uncertain composition, the following being the mean results:—

$$C = 68{\cdot}64, \qquad H = 8{\cdot}81, \qquad N = 9{\cdot}63.$$

This composition agrees most closely with the formula $C_{16}H_{24}N_2O_2$, which requires—

$$C = 69{\cdot}56, \qquad H = 8{\cdot}69, \qquad N = 10{\cdot}1.$$

Such a body might be formed according to the following equation:—

$$3C_6H_9N + 2H_2O = C_{16}H_{24}N_2O_2 + \underset{\text{Ethylamine.}}{C_2H_7N},$$

and, in fact, when potash has been used as a precipitant, it is easy to detect abundance of ethylamine in the filtrate. The powder melts at 165°–170°C., but not sharply. It is soluble in all acids (except nitric acid) even when dilute. On evaporating the solution in hydrochloric acid on the water-bath, the hydrochlorate remains in the form of blood-red scales, showing no trace of crystalline form. These re-dissolve easily in water. The base is precipitated from its acid solutions by minute quantities of nitric acid or nitrates, as a flocculent brown powder. Bromine or chlorine water, stannic and mercuric salts, likewise precipitate it. In its characters and composition it approaches some of the amorphous alkaloids extracted from cinchona bark.

Pyrrol-red (which, however, is entirely destitute of basic properties) is produced from pyrrol in a perfectly similar way,

$$3C_4H_5N + H_2O = C_{12}H_{14}N_2O + NH_3.$$

Carboxyl derivatives of Pyrrol.

In my former paper I mentioned that when the primary amine salts of mucic acid are distilled, there are produced, besides substituted pyrrols, a series of bodies having the composition of amides of mono-

and di-carboxyl derivatives of these pyrrols. The corresponding acids had not at that time been procured. These amides are rather stable compounds, and are very slowly attacked by mineral acids and alkalis.

If it is attempted to decompose them by prolonged boiling with strong alkaline solutions, it is impossible to prevent the decomposition of the acids as fast as formed. I have found, however, that they may be easily split up by enclosing them in sealed tubes with strong alcoholic potash, and exposing the tubes for some time to a temperature of about 120°C. They are then resolved with facility into free ammonia-base and the potash salts of the corresponding acids; thus—

Dimethyl-carbopyrrolamide. Methyl-carbopyrrolic acid.

$$C_4H_3N(CH_3)(CONHCH_3) + KHO = C_4H_3N(CH_3)COOK + NH_2CH_3.$$

Diethyl-carbopyrrolamide. Ethyl-carbopyrrolic acid.

$$C_4H_3N(C_2H_5)CONHC_2H_5 + KHO = C_4H_3N(C_2H_5)COOK + NH_2C_2H_5.$$

I have not, however, been able to obtain amyl-carbopyrrolic acid. Its amide when heated with potash yields amyl pyrrol, amylamine, and potassic carbonate.

$$C_4H_3N(C_5H_{11})CONHC_5H_{11} + 2KHO = C_4H_4N(C_5H_{11}) + K_2CO_3 + NH_2C_5H_{11}.$$

The potassium salts of these acids are obtained in the solid form by evaporating their alcoholic solutions. They are very soluble in water and alcohol. By cautiously adding to their concentrated aqueous solutions dilute hydrochloric acid in *very slight* excess, the mixture being carefully cooled from time to time, the acids are separated as flocculent precipitates which soon become crystalline. The crystals must be rapidly washed with cold water. To remove small quantities of silica (derived from the glass tubes) they must be dissolved in ammonia and again precipitated with hydrochloric acid. When thoroughly free from mineral acid they may be crystallized from water at about 90°C. (not higher), in which they are freely soluble.

Methylcarbopyrrolic acid crystallizes in needles which are very soluble in alcohol and ether. It melts at 135°C.; heated a little beyond this point, it breaks up into methyl-pyrrol and carbonic anhydride.

$$C_4H_3N(CH_3)COOH = C_4H_4N(CH_3) + CO_2.$$

It volatilizes with partial decomposition in a current of steam. Its salts are as a rule easily soluble in water: those of the alkalis and alkaline earths dissolve in alcohol. *Argentic methyl-carbopyrrolate* $C_4H_3N(CH_3)COOAg$, obtained by double decomposition, crystallizes from much boiling water in transparent prisms which deflagrate feebly when heated. ·446 grams of the finely powdered salt, mixed with sand to avoid loss by too rapid decomposition, gave on cautious ignition ·206 grams of silver = 46·19 per cent.; calculated = 46·55 per cent.

Ethylcarbopyrrolic acid, similarly prepared, bears a great resemblance to the methylated acid. It is, however, rather less stable, more soluble in water, and melts at 78°C. The silver salt is much more

soluble in boiling water than that of the previous acid. Found, 43·89 per cent. of silver; calculated, 43·9 per cent.

In contact with boiling water, or in the cold in presence of even highly dilute mineral acids, these two acids are rapidly resolved into methyl- or ethyl-pyrrol and carbonic anhydride. Their solutions in water below its boiling point are tolerably stable so long as they are contained in smooth glass vessels; but rough surfaces (filter paper) or fine points cause rapid decomposition. They give with neutral ferric chloride a red colour.

Ethyl-dicarbopyrrolic acid.—$C_4H_2N\ (C_2H_5)\ (COOH)_2$ is obtained by the action of large excess of alcoholic potash at 130° C, upon *triethyl-dicarbopyrrolamide*, one of the decomposition products of ethylammonium mucate. The potassium salt crystallizes from alcohol in long needles. The acid is obtained from its aqueous solution by precipitation with hydrochloric acid. It appears as a sandy powder, quite insoluble in boiling water, and not decomposed by it. It is easily soluble in alcohol and ether. By crystallization from dilute alcohol it is procured in brilliant needles, which when heated do not melt, but at about 250° C. are resolved into ethyl-pyrrol and carbonic anhydride.

$$C_4H_2N(C_2H_5)\ (COOH)_2 = C_4H_4N(C_2H_5) + 2CO_2$$

Analysis gave the following results :—

Found.		Calculated.
C = 52·26	. . . . .	52·26
H = 5·27	. . . . .	4·91
N = 7·96	. . . . .	7·65

The nitrogen determination was a little too high, owing to the accidental employment of slightly impure soda-lime.

The salts of this acid are mostly soluble in water. The silver salt is an insoluble sandy powder. Found, 53·97 per cent. Ag: calculated for, $C_4H_2N(C_2H_5)\ (COO\,Ag)_2$ = 54·4 per cent.

The acid is very slowly decomposed in the cold by concentrated hydrochloric acid. Boiling dilute nitric acid dissolves it, but deposits it unchanged on cooling. Strong and warm nitric acid also dissolves it, but does not again deposit it on dilution.

About two per cent. of its weight of this acid may be obtained from the mucate of ethylia.

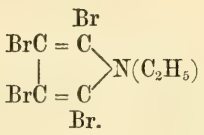
Action of Bromine upon Pyrrol Derivatives.

When bromine is added to a solution of ethyl-pyrrol in ether or chloroform, the mixture becomes dark-coloured and gives off hydrobromic acid. The reaction takes place with greater smoothness when alcohol is used as a solvent; but the best result is attained when ethyl-pyrrol is shaken with excess of bromine water, added gradually.

The insoluble solid compound formed is filtered off and repeatedly crystallized from boiling spirits of wine, in which it is sparingly soluble in the cold. It then crystallizes in brilliant colourless needles which melt at 90° C., or beneath warm spirit. They are easily decomposed above 100° C. It might have been expected that a body so poor in hydrogen as ethyl-pyrrol would have given an addition compound with bromine. But analysis shows that towards this reagent the pyrrol nucleus behaves like benzol.

	Found.	Calculated for. $C_4Br_4NC_2H_5$
C	= 17·3	17·51
H	= 1·43	1·21
Br	= 77·2	77·85
N	= —	—

The compound remains apparently unchanged when digested with excess of bromine water. No doubt it has the following constitution:—



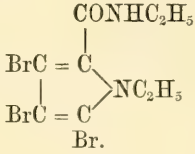
Diethylcarbopyrrolamide, $C_9H_{14}N_2O$, also does not unite directly with bromine. When bromine dissolved in chloroform is added to a chloroform solution of the amide, it is at once decolourized: but even in the cold, fumes of hydrobromic acid are given off, and, on allowing the chloroform to evaporate, a tenacious mass is left, in all probability a mixture of unchanged amide with a substitution compound.

When shaken with bromine water, diethylcarbopyrrolamide yields an insoluble substitution compound and a soluble oxidation product. To obtain the first, careful manipulation is required, since it passes into the second with the greatest ease. The amide is first dissolved by continued agitation in so much warm water that nothing separates on cooling. Bromine water is then dropped in very cautiously, the mixture being shaken after each addition. The two new compounds are produced simultaneously, the first separating in small clots, and rendering the mixture milky. On continuing the addition of bromine, a point is reached at which the milkiness suddenly disappears, and the liquid becomes transparent, while the clots adhere to the sides of the flask. This clearing marks the point at which all the amide has been acted upon, and any further quantity of bromine added is used up in oxidizing the clots. The liquid is filtered, and the solid residue is repeatedly crystallized from 60% alcohol, in which it is freely soluble on heating. It separates on cooling, when pure, as a jelly-like mass of long silky needles of extreme tenuity, which require prolonged heating to 100° C. to dry them. The substance is insoluble in water,

but dissolves with facility in alcohol or glacial acetic acid. It melts with partial decomposition at 120° – 121° C. Analysis gave the following numbers :—

Found.	Calculated for. $C_9H_{11}Br_3N_2O$
C = 26·65	26·79
H = 2·95	2·73
Br = 59·36	59·55
N = —	—

It is evidently derived from the amide by the substitution of three atoms of bromine for three atoms of hydrogen. Its constitution is most probably



When the clear liquid from which this body has been filtered off is evaporated on the water-bath, much hydrobromic acid escapes, and a crystalline body is deposited. This must be removed before the liquid has gone quite to dryness, and it is then easily purified by crystallization from water or alcohol. The new body forms small hard transparent crystals which melt with decomposition at 197° C. It dissolves easily in all alkalis, and is reprecipitated by dilute acids. Its ammoniacal solution, when evaporated to dryness on the water-bath, leaves a residue which is not dissolved by water, and which appears to be the original body, still, however, containing a little ammonia. This is not the behaviour of a true acid. Boiling with fixed alkalis decomposes it completely, ethylamine, alkaline bromide, and other bodies not as yet investigated, being formed. Analysis leads to the formula $C_9H_{11}Br_2N_2O_3$.

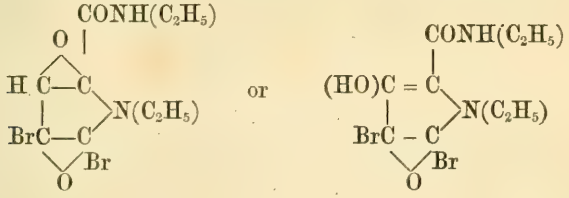
Found.	Calculated.
C = 30·08	30·42
H = 3·31	3·09
Br = 44·87	45·07
N = 7·8	7·88
O = —	—

This compound is also obtained when the tribrominated diethylcarbopyrrolamide is treated with bromine water. The reaction is perhaps the following :—

$$C_9H_{11}Br_3N_2O + Br_2 + 2H_2O = C_9H_{11}Br_2N_2O_3 + 4HBr.$$

It is not, however, easy to frame a constitutional formula for it which shall be in harmony with such a change, unless we suppose

that it contains one atom of hydrogen more than is indicated by analysis, and give to it some such structure as the following :—



either of which would require 3·37 per cent. of hydrogen.[1] This view is quite justified by the analysis of the corresponding methyl-compound given below. The second formula would have the advantage of accounting for the property of the compound of dissolving in alkaline solutions. As I have pointed out, the ammonia compound is decomposed by simple heating on the water-bath, which would seem to point to the presence of a hydroxyl group. It is unlikely that any oxidizing action has been exerted upon either of the lateral groups, C_2H_5; for, firstly, the compound readily evolves ethylamine when heated with caustic potash, and secondly, tetrabrominated ethyl-pyrrol is scarcely attacked even when heated with bromine water.

From *dimethylcarbopyrrolamide* similar bodies may be obtained by shaking with bromine water. I have not isolated the first of these, having had only a small quantity of amide to work with: but the second or oxidized compound is obtained as easily as its ethyl-analogue, which it resembles in crystalline form, solubility, &c. It melts, however, at a higher temperature, 204° – 205° C., at the same time decomposing. I give a partial analysis of it.

Found.	Calculated for. $C_7H_8Br_2N_3O_3$
C = 25·27	25·6
H = 2·61	2·44
Br = 48·23	48·78

The study of the action of potash and of reducing agents upon these bodies will probably explain their constitution.

[*Note added in the Press.*]

[1] A more carefully prepared specimen of the body gave, on analysis, C = 30·42 and H = 3·64; agreeing well with the formula $C_9H_{12}Br_2N_2O_3$, which requires C = 30·34, H = 3·37 per cent.

XXIX.—On the Distillation Products of the Saccharates of Ammonium and Ethylammonium. By Edwin Lapper, F.C.S., L.C.P.I., and Chichester A. Bell, M.B., Univ. Dublin.

[Read, June 24, 1878.]

In a former communication,[1] one of us has shown how that by the action of heat upon the mucates of the fatty amines, a series of bodies is produced which may be regarded as substitution compounds of the base *pyrrol*, C_4H_5N, obtained by the dry distillation of ammonium mucate. Amongst these is a dicarboxyl derivative of ethyl-pyrrol, $C_4H_2N(C_2H_5)(COOH)_2$, the formation of which is of peculiar interest, since it shows that the production of the pyrrol nucleus from mucic acid is not dependent on the separation of its carboxyl groups.

In the hope of being able to throw some light upon the isomerism of mucic and saccharic acids, we have now studied the action of heat on the saccharates of ammonium and ethylammonium. It appeared to us very probable that by this action we would obtain either bodies isomeric with those from mucic acid, or totally different products; and that, in either case, we might be able to draw conclusions as to the constitution of the two acids. In one respect our expectations have not been fulfilled: nevertheless, our experiments have established an interesting difference in the deportment of the two acids, which may at some future time be of importance in determining their constitution.

Ammonium saccharate was prepared exactly according to the directions given by Liebig. The acid was purified by crystallization of its acid ammonium salt, which was then converted into the neutral salt.

The saccharate is most conveniently heated in a capacious glass retort, by means of a paraffin bath. Decomposition begins when the bath is heated to 136° C., and takes place quickly at 160° C. After some time the whole of the saccharate disappears, leaving only a slight carbonaceous residue in the retort. Ammonia and carbonic anhydride escape in large quantity, and the liquid in the receiver consists of an aqueous solution of ammonium carbonate, covered by a layer of oily liquid. The neck of the retort is covered with numerous crystals, but these consist entirely of ammonium carbonate. On careful evaporation on the water bath, the watery distillate leaves only a trace of non-volatile matter. The oily layer, after being washed, dried, and rectified, possesses all the characters, boiling-point, specific gravity and reactions, of ordinary pyrrol, its identity with which is thus satisfactorily proved. The following equation expresses the reaction—

$$C_6H_{10}O_8(NH_3)_2 = C_4H_5N + 2CO_2 + NH_3 + 4H_2O.$$

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[1] "Proceedings," Second Series, vol. iii., Science, p. 33.

Pyrrol is obtained in almost theoretical quantity; and if ammonium saccharate could be conveniently prepared, it would undoubtedly be the best source of the base.

With this equation we may contrast the action of heat upon ammonium mucate, by which not only pyrrol, but also *carbopyrrolamide*, is formed—

$$C_6H_{10}O_8(NH_3)_2 = C_4H_4N(CONH_2) + CO_2 + 5H_2O.$$

The amide, by boiling with baryta-water, is easily converted into *carbopyrrolic acid;* and this acid when heated splits up into pyrrol and carbonic anhydride—

$$C_4H_4N(COOH) = C_4H_5N + CO_2.$$

Since ethylamine acts upon mucic acid differently from ammonia, we have also studied the action of heat upon ethylammonium saccharate.

To obtain this salt, and to avoid the tedious preparation of free saccharic acid, we took equivalent weights of acid ammonium saccharate and diethyloxamide. The first was converted into neutral salt, and to its concentrated aqueous solution, carefully freed from excess of ammonia, we added the neutral sulphate of ethylia prepared from the diethyloxamide. The mixture was evaporated to dryness *in vacuo* at a gentle heat, and the residue exhausted with absolute alcohol, which extracts only ethylammonium saccharate. After evaporating the alcohol, the salt remained as a syrupy mass, which showed little tendency to crystallize. It was therefore at once distilled.

Ethylammonium saccharate decomposes with intumescence at about 120° C., exhibiting the same appearances as the ammonia salt, except that no crystals are formed in the neck of the retort. The watery liquid which collects in the receiver contains only ethylammonium carbonate, and the oily layer consists of nearly pure ethylpyrrol in almost theoretical amount. The equation—

$$C_6H_{10}O_8(NH_2C_2H_5)_2 = C_4H_4N(C_2H_5) + 2CO_2 + NH_2C_2H_5 + 4H_2O,$$

represents the decomposition. A most careful examination failed to detect any other substance either in the distillate or in the residue. The latter was exceedingly small.

Ethylammonium mucate, on the other hand, breaks up by heat in the following ways:—

(1). $C_6H_{10}O_8(NH_2C_2H_5)_2 = C_4H_4N(C_2H_5) + 2CO_2 + NH_2C_2H_5 + 4H_2O$;

(2). $C_6H_{10}O_8(NH_2C_2H_5)_2 = C_4H_3N(C_2H_5)CONHC_2H_5 + CO_2 + 5H_2O$,

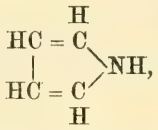
and by the action of nascent ethylamine from reaction (1),

(3). $C_6H_{10}O_8(NH_2C_2H_5)_2 + NH_2C_2H_5 = C_4H_2N(C_2H_5)(CONHC_2H_5)_2 + 6H_2O.$

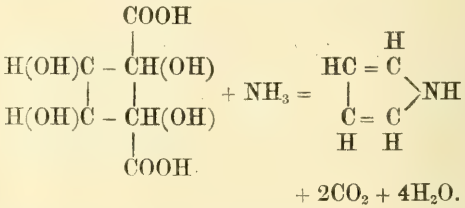
With regard to the cause of the difference in the behaviour of the two acids, but little can be said. According to all experiments hitherto published, it is extremely probable, if not absolutely certain, that the relative position of the carbon atoms is the same in both. Both are *normal* compounds; and the differences between them must be due to the positions of their hydroxyl groups. If we give to either acid (*e. g.* mucic acid) the formula

$$CO_2H - CH(OH) - CH(OH) - CH(OH) - CH(OH) - CO_2H,$$

and to pyrrol the constitution proposed by Baeyer,



the formation of the latter is easily explained—



$$+ 2CO_2 + 4H_2O.$$

At the same time one or both of the carboxyl groups may become amidated, and may remain with the pyrrol nucleus. In saccharic acid now we may imagine a greater number of hydroxyl groups to be joined to the carbon atoms in the neighbourhood of the carboxyl, and consequently the latter to be rendered unstable. Hence, when ammonium saccharate is distilled, it parts with both carboxyl groups, and gives pyrrol, but no carbopyrrolic acid. This explanation is reasonable, for we know that oxyacids as a rule lose CO_2 much more easily than the acids from which they are derived, and those in which the OH is near the carboxyl more easily than those in which it is remote from it. Thus, succinic acid, when heated, yields an anhydride, whilst tartaric acid (dioxysuccinic acid) decomposes into carbonic anhydride and pyroracemic acid. Again, salicylic acid separates more easily into phenol and CO_2 than either of its isomerides, para- and meta-oxybenzoic acids; whilst benzoic acid may be distilled unchanged. Many similar examples might be adduced.

We purpose studying the action of ammonia on other highly oxygenated acids.

XXX.—Computation of Tides at Fleetwood.—Discussion of Corresponding Phenomena in different Years, etc.

By James Pearson, M. A., Ex-Scholar (15th Wrangler), Trinity College, Cambridge.

[Read, November 11, 1878.]

In my first[1] communication on the subject of the Tides, I gave a brief account of the guiding principles which led me to the construction of revised Tables for their computation, and the graphic process by which I obtained a clue to them. My second[2] Paper showed the results of theory as compared with observation, and proved that the course of the "diurnal inequality" was correctly explained and traced out. The object of my present Paper is to illustrate the correspondence of tides in different years, having the same constituents approximately. If a velocity of angular rotation, equal and opposite to that of the earth, be supposed to be communicated to the moon, the earth will be reduced to rest, and the moon's path in the sky will be represented by a sort of spherical helix, the convolutions of which will ascend from east to west, whilst the moon's declination passes from south to north; and during that interval the path of the "anti-moon" will be also represented by a corresponding spherical helix, but differing from the former in this respect, that its convolutions will descend from east to west, whilst the actual moon's declination has the fore-mentioned changes. To use a familiar illustration—in the one case we shall have a left-handed cork-screw motion, and in the other a right-handed one. Consequently, the lunar and anti-lunar tides are essentially different in their operation, and so are the solar and anti-solar tides. On the method which I have adopted in dealing with the subject, any single tide during any year will only have one tide corresponding to it, out of all the tides in any other year, and hence it becomes interesting to inquire how far such co-ordinate tides (as I may term them) agree with observation as years advance; and with this purpose in view, I will select a series of such tides, commencing with the year 1873, and occurring in the same month (April) in each year subsequent; also another series occurring in the same month (September) in each year. The results will speak for themselves; but I would invite attention to the tides for 1872, Sept. 15, evening, and 1873, Sept. 5, evening. These have almost identical constituents; and yet, from atmospheric causes, we have in one case a resulting tide three inches above calculation, and in the other a resulting tide eleven inches below.

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[1] *Vide ante*, page 72. [2] *Vide ante*, page 111.

Computation of Tides.

Anti-lunar and Solar.	1874, April 26, Morning.		1875, April 15, Morning.		1876, April 4, Morning.		1877, April 23, Morning.		1878, April 13, Morning.	
	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.
Moon's Transit, .	7 25′	21 2	7 7	20 9	7 16	20 11	7 12	21 0	7 18	21 0
Inc. for Anti-lunar,		− 1		− 1		− 1		− 1		− 1
Moon's Hor. Parallax,	55′ 0″ −	− 5	57′ 17″ −	+ 5	58′ 55″ −	+ 14	59′ 21″ +	+ 14	59′ 0″ +	+ 12
Moon's Declination,	19° 55′ S. asc.	0	24° 2′ S. asc.	− 6	25° 2′ S. asc.	− 8	12° 28′ S. asc.	+ 3	19° 43′ S. asc.	+ 0
Sun's Declination, .	13° N.	+ 2	9° N.	+ 1	5° N.	+ 1	12° N.	+ 1	8° N.	+ 1
	ft. in.		ft. in.		ft. in.		ft. in.		ft. in.	
	20 9 obs.	20 10	20 8 obs.	20 8	21 7 obs.	21 5	22 2 obs.	22 5	22 2 obs.	22 0

Lunar and Anti-solar.	1872, Sept. 15, Evening.		1873, Sept. 5, Evening.		1874, Sept. 24, Evening.		1875, Sept. 13, Evening.		1877, Sept. 20, Evening.	
	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.
Moon's Transit, .	21 37	24 5	21 48	24 8	21 56	24 9	21 34	24 5	21 48	24 8
Inc. for Lunar, . .		+ 5		+ 5		+ 5		+ 5		+ 5
Moon's Hor. Parallax,	60′ 25″ +	+ 20	60′ 27″ +	+ 20	59′ 36″ +	+ 15	56′ 27″ +	+ 0	54′ 2″ +	− 12
Moon's Declination,	21° 22′ S. asc.	− 2	23° 24′ S. asc.	− 4	17° 23′ S. asc.	+ 3	22° 1′ S. asc.	− 3	15° 22′ S. asc.	+ 4
Sun's Declination, .	4° S.	+ 5	7° S.	+ 4	0° S.	+ 5	5° S.	+ 5	2° S.	+ 4
	ft. in.		ft. in.		ft. in.		ft. in.		ft. in.	
	27 0 obs.	26 9	25 10 obs.	26 9	27 1 obs.	27 1	24 8 obs.	25 0	24 7 obs.	24 9

It may be of interest to place on record examples of the most extreme cases of high and low tides which I have as yet observed. The tides in these instances were produced, of course, under circumstances least favourable and most favourable to their development.

	1876, March 19, Evening, Anti-lunar and Anti-solar.		1874, March 19, Evening, Lunar and Solar.	
	h. m.	ft. in.	h. m.	ft. in.
Moon's Transit, ...	18 8	20 0	11 55	26 3
Inc. for Lunar or Anti-lunar,		− 4		+ 7
Moon's Horizontal Parallax,	54′ 14″ −	− 12	61′ 22″ +	+ 27
Moon's Declination, . . .	28° 44′ N. asc. des.	− 19	5° 27′ S. asc.	+ 14
Sun's Declination, . . .	1° S. N.	− 3	0°	+ 7
	ft. in.		ft. in.	
	15 8 obs.	16 10	30 11 obs.	30 10
	(Helbrè Island.)			

In the former case the tide fell fourteen inches below its expected height; but the barometer on this occasion stood at 30°·7′, and the wind was very cold and heavy from the North. Such a low tide had not been remembered for at least twenty years.

Annexed are comparisons for the month of September, 1878.

Date.	Calculation.	Increm. or Decrem.	Observation.	Increm. or Decrem.	Remarks. Barom., Wind, &c.
1878.	ft. in.	in.	ft. in.	in.	
Sept. 12,	25 10	+ 18	25 9	+ 9	30·2 W.N.W., half gale.
	27 4	− 15	26 6	− 9	30·3 W.N.W., signal flying.
„ 13,	—	—	—	—	
	26 1	+ 14	25 9	+ 18	30·4 W.N.W., calm.
„ 14,	27 3	− 18	27 3	− 18	30·1 W.S.W., calm.
	25 9	+ 9	25 9	+ 9	30·0 W.S.W., calm.
„ 15,	26 6	− 18	26 6	+ 5	29·9 S.W., freshening.
	25 0	+ 6	26 11	+ 11	29·4 S.W., equinoctial.
„ 16,	25 6	− 19	27 10	− 18	29·5 N.W., gale.
	23 11	+ 4	25 6	− 6	29·8 N.N.W., abating.
„ 17,	24 3	− 18	25 0	− 7	29·9 W.S.W., backing.
	22 9	0	24 5	− 3	29·8 W.S.W., backing.
„ 18,	22 9	− 17	24 2	− 15	29·7 N.W., strong.
	21 4	+ 1	22 11	− 1	29·7 W., strong.
„ 19,	21 5	− 14	22 10	− 17	29·8 W., half gale.
	20 3	− 6	21 5	− 23	29·9 W., unsettled.
„ 20,	19 9	− 11	19 6	− 10	30·1 W., gusty.
	18 10	− 3	18 8	− 3	30·4 W., calm.

Date.	Calculation.	Increm. or Decrem.	Observation.	Increm. or Decrem.	Remarks. Barom., Wind, &c.
1878.	ft. in.	in.	ft. in.	in.	
Sept. 21,	18 7	+ 7	18 5	+ 8	30·4 W., calm.
	19 2	+ 7	19 1	+ 16	30·3 signal out.
„ 22,	19 9	+ 16	20 5	+ 7	30·0 S.S.W., fresh.
	21 1	+ 11	21 0	+ 16	29·8 S., calm, heavy rain.
„ 23,	22 0	+ 15	22 4	+ 13	29·6 S.W. to N.W., signal out.
	23 3	+ 12	23 5	+ 4	29·7 N.W., calm.
„ 24,	24 3	+ 20	23 9	+ 22	30·0 N.W., gusty.
	25 11	+ 17	25 7	+ 22	30·0 W, gusty.
„ 25,	26 4	+ 17	27 5	+ 5	29·6 S.W., falling fast.
	27 7	+ 6	27 10	+ 5	29·7 N.N.W., fresh, cold.
„ 26,	28 3	+ 20	28 3	+ 20	30·0 N.W., calm.
	29 8	− 5	29 11	− 8	30·0 W.S.W., calm.
„ 27,	29 3	+ 11	29 3	+ 10	30·0 W., calm.
	30 2	− 6	30 1	− 5	30·1 W., calm.
„ 28,	—	—	—	—	
	29 8	+ 1	29 7	+ 4	30·0 W., calm.
„ 29,	29 9	− 12	29 11	− 13	30·0 W., calm.
	28 9	—	28 10	—	30·0 W., calm.

XXXI.—COMPUTATION OF OCCULTATIONS AND ECLIPSES.

By JAMES PEARSON, M. A., F. R. A. S., late Scholar of Trinity College, Cambridge, Vicar of Fleetwood.

[Read, February 10, 1879.]

THE methods of calculating the circumstances connected with the above phenomena, as given by Mr. Woolhouse in the appendix to the *Nautical Almanac* for 1836, or as contained in Admiral Shadwell's work on the subject, are confessedly so laborious and puzzling, that any arrangement by means of which the same results might be obtained with more facility must be esteemed desirable. The graphic process delineated by Mr. Penrose in his valuable treatise is a step in this direction, but it is capable of being so modified as that it can be easily performed in about twenty minutes, and bring out the times of occurrence within thirty seconds. To explain the mode by which this is accomplished is the object of the present communication.

For ordinary use in these operations it is necessary first to construct a series of concentric ellipses, having a common semi-axis major ten inches in length. The semi-axes minor are in the same straight line, but are of lengths 10 sin 2°, 10 sin 4°, 10 sin 6°, &c., up to 28°, which is the extreme range of the moon's declination. Ordinates are drawn to the semi-axis major, the abscissæ of which are successively 10 sin 15°, 10 sin 30°, 10 sin 45°, &c., corresponding to the hours I, II, III, &c. The construction of this diagram will not be a matter of much difficulty to those who are acquainted with the elements of Conic Sections, and it must be treasured up for subsequent use, being the only diagram required in the process.

The next step is to construct a scale of equal parts, the length of ten divisions of which is represented by the number $\frac{10000}{P\rho \cos l'}$, where P is the moon's reduced relative Horizontal Parallax, ρ the factor which deduces the Earth's radius at the proposed place from the equatorial radius, and l the *geocentric* latitude. Since this scale involves both the latitude and the parallax, it is called the latitude-parallax-scale, and the number referred to is to be taken from an ordinary inch-diagonal navigation scale. This done, the moon's reduced horary motion in right ascension, and given horary motion in declination, will enable us to lay down the moon's relative orbit by its aid, which orbit must be subdivided into hours and minutes by the compasses, commencing at the instant of the moon's true conjunction. The position of the centre of the projection of the parallel of latitude of the given place must be found by the number representing,

$$\{\text{diff. dec.} - P\rho \sin l \cos \delta\},$$

the notation being the same as before; and it will be below or above the moon's centre at conjunction according as the above quantity is + or −; and this being ascertained, the ellipse-diagram will guide in tracing out as much of the ellipse as is traversed during the progress

of the eclipse, and in subdividing it into intervals of hours and minutes. Lastly, from the latitude-parallax-scale is taken an extent equal to the sum of the semi-diameters reduced of the sun and moon, and one foot being set on the moon's path and the other on the path of the observer, the compasses are moved backwards and forwards till the points fall into the same hour and minute in both paths, thus showing the required times.

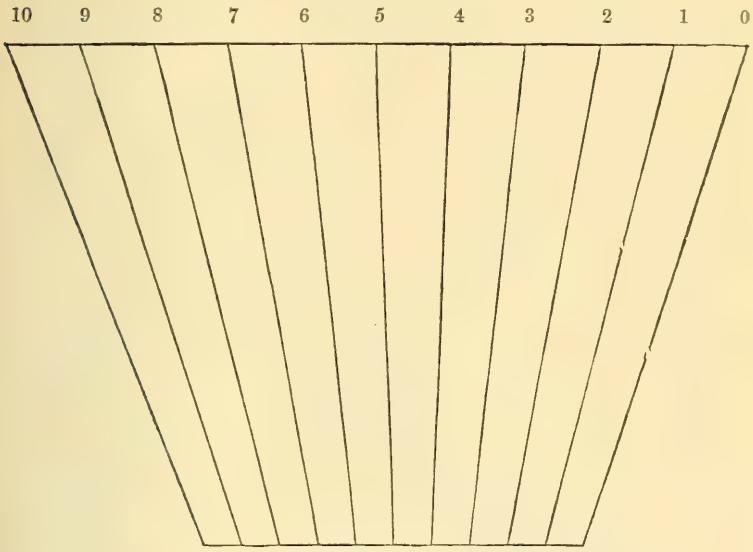
To facilitate the subdivision of the latitude-parallax-scale, and of the hours on the moon's path, two diagrams may be drawn as on page 185, only enlarged in magnitude :—

The moon's horary motion in right ascension is taken from the "variations for 10^m," given in the *Nautical Almanac*, by calling the seconds of *time* minutes of *arc*, and increasing these quantities half as much again. The moon's horary motion in declination is taken from the corresponding quantities in the same page, by regarding the *seconds* of arc as *minutes* of arc, and dividing by 10.

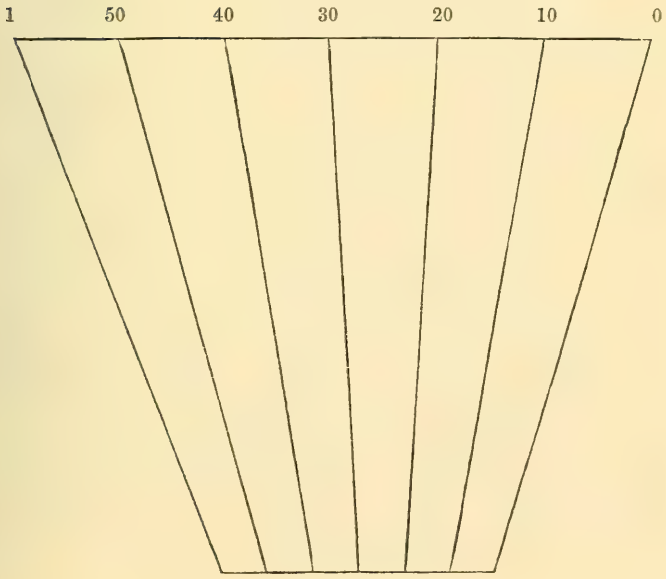
TABLE *of Values of Ten Divisions of the Latitude-Parallax-Scale, and of* Pρ sin *l*, *for Greenwich Lat. Geoc.* 57° 17′ N., *used in construction of Occultations and Eclipses.*

Horizontal Parallax.	Value of Ten Divis.	Difference.	Pρ sin l ×	Difference.	Horizontal Parallax.	Value of Ten Divis.	Difference.	Pρ sin l ×	Difference.
53′·0	302·4	1·2	41′·28	·15	58′·0	276·3	1·0	45′·17	·16
·2	301·2	1·1	·43	·16	·2	275·3	·9	·33	·15
·4	300·1	1·1	·59	·16	·4	274·4	1·0	·48	·16
·6	299·0	1·1	·75	·16	·6	273·4	·9	·64	·15
·8	297·9	1·2	·91	·15	·8	272·5	·9	·79	·16
54′·0	296·7	1·1	42′·06	·15	59′·0	271·6	1·0	·95	·15
·2	295·6	1·0	·21	·16	·2	270·6	·8	46′·10	·16
·4	294·6	1·1	·37	·15	·4	269·8	·9	·26	·15
·6	293·5	1·1	·52	·16	·6	268·9	·9	·41	·16
·8	292·4	1·1	·68	·15	·8	268·0	·9	·57	·16
55′·0	291·3	1·0	·83	·16	60′·0	267·1	·9	·73	·15
·2	290·3	1·1	·99	·16	·2	266·2	·9	·88	·16
·4	289·2	1·0	43′·15	·15	·4	265·3	·9	47′·04	·15
·6	288·2	1·0	·30	·16	·6	264·4	·8	·19	·16
·8	287·2	1·1	·46	·15	·8	263·6	·9	·35	·16
56′·0	286·1	1·0	·61	·16	61′·0	262·7	·9	·51	·15
·2	285·1	1·0	·77	·15	·2	261·8	·8	·66	·16
·4	284·1	1·0	·92	·16	·4	261·0	·9	·82	·15
·6	283·1	1·0	44′·08	·16	·6	260·1	·8	.97	·16
·8	282·1	1·0	·24	·15	·8	259·3	·8	48′·13	
57′·0	281·1	1·0	·39	·16					
·2	280·1	·9	·55	·15					× cos δ.
·4	279·2	1·0	·70	·16					
·6	278·2	1·0	·86	·15					
·8	277·2	·9	45′·01						
58′·0	276·3	·10	·17						
			× cos δ.						

FOR LATITUDE-PARALLAX-SCALE.



FOR MOON'S HORARY-SCALE.



XXXII.—On the Supernumerary Rings of the Rainbow. By Philip Burton.

[Read November 11, 1878.]

The explanation of the rainbow, which was given by Sir Isaac Newton in his "Optics," did not comprise any account of the coloured rings frequently to be seen within the violet of the primary bow, and, more rarely, outside that of the secondary; nor is it probable that these phenomena had been noticed when he wrote. The theory thus remained defective until 1803, when Dr. Young showed that the supernumerary colours were caused by the interference of two portions of light, which, though incident upon the drops of rain at different angles, were emitted parallel, and reached the eye, after having traversed unequal spaces. According to this principle, the places of the additional rings, with respect to the primitive rainbows, must vary with the size of the drops by which they are formed; but a different method of estimating the effects of interference, devised by Sir G. Airy in 1838, seems to be generally adopted at the present day. In the account of the latter system, which is given in a recent publication,[1] it is stated universally that the calculation shows "there is a succession of feebler and feebler concentric circles of maximum brightness—inside the principal maximum in the primary bow, and outside it in the secondary"; and no reference being made to the effect of different dimensions of the drops, the results obtained would seem to be independent of such variation, from which it may be inferred that the phenomena are always similar, and that all the drops are equally effective to produce them. As many appearances of these bows have come under my notice, I can perceive that the conclusions now referred to are not warranted by observation; I am, therefore, induced to put forward this Paper, in which I shall endeavour to show that the positions and breadth of the interference bows do actually vary within certain limits, though not perhaps to the extent which Dr. Young's theory would seem to require; also, that the phenomena in question can only be produced by drops, which do not exceed a certain size.

The most usual appearance presented by the additional bows agrees very well with the description given in 1722 by Dr. Langwith, who seems to have been one of the first to observe them. "The colours of the primary bow," he says, "were as usual, only the purple very much inclining to red, and well defined: under this was an arch of green, then alternately two arches of reddish purple, and two of green, and under all a faint appearance of another arch of purple. . . . We had here four orders of colours, and perhaps the beginning of a fifth; and the breadth of the first series so far exceeded that

[1] Chambers' "Encyclopædia."

of any of the rest, that, as near as I could judge, it was equal to them all taken together." (*Philosophical Transactions*, vol. xxxii., p. 243.) On several occasions I have seen bows corresponding with this description; but the breadth of the colours was not always the same, being sometimes very narrow, and at other times more considerable. It does not often happen that so many coloured rings become visible together, though in almost every rainbow I find that the first additional ring of green can be observed in contact with the primitive violet: the appearance of a reddish or purple ring within the green is also not unusual; and on less frequent occasions these colours are repeated in the same order. In almost every instance we can see that the interference rings decrease in brightness as they recede from the primitive bow, and they are also narrower than the rings which compose the latter.

On the 26th of June, 1877, at 7·40 p.m., I observed a rainbow with supernumerary rings differing in some particulars from those now mentioned. In this instance there was in contact with the violet a ring of red, which was followed by other rings in this order—green, red, green, red, green, red. These colours were almost as bright as those of the principal bow; and although the last ring of red seemed as brilliant as any of the others, there was no indication of any fainter rings beyond it. They were not formed at all parts of the arc, but only in positions where the sun seemed to shine strongly; also, the breadth of each ring seemed to be equal to the sun's diameter; and the colours observed were red and green—not purple and green, as they usually appear.

The additional colours on the outside of the secondary bow are very rarely seen on account of their faintness; indeed, I have not been able to notice in this position more than a single green ring, and that only on a few occasions.

An important principle in connexion with the supernumerary colours is, that there is a limit to the size of the drops in which they are formed; so that, although the smaller drops may produce them, those of larger size are quite inefficient to do so. This principle may be expected, from Dr. Young's theory; for it appears, from his mode of calculation, that the number of returns of the rays within a given distance from the caustic increases with the size of the drops: consequently, the rings being more numerous in equal spaces, the breadth of each must diminish as the drops grow larger; and when a certain limit is attained, the opposite colours being very close, will reach the eye compound or white, just as if no interference took place. That this is really the case may be shown by examining the coloured rings produced by single drops of rain in the following manner:—

If we take a fine hair, or a slender fibre of flax, &c., and, holding both ends of it in the fingers, immerse it in water, again withdrawing it in such a manner as will cause some particles of the fluid to adhere to it; upon bringing one of these particles very close to the eye, and in

a proper position, whilst at the same time the sun shines upon it, we shall observe a brilliant arc of rainbow lying apparently within the drop, and accompanied by many supernumerary rings. The colours of these rings are alternately green and purple, and they are all concentric with the principal bow. If we now alter the position of the drop a little towards the sun, these colours will disappear, and the secondary bow, encircled with brilliant supernumerary rings on its outside, will come into view. By changing the position of the drop with respect to the eye, at the same time retaining it at the proper elongation from the sun, we get a view successively of every portion of the arcs produced by the drop, and can perceive that the form of each bow is nearly that of a circle, convex to the sun. The curvature of the caustic for the secondary bow is much greater than that of the primary, so that within the limits of the visible arcs it is seen to intersect the primary at two points equally distant from the centre of the drop, its supernumerary rings converging towards it as they approach those points.

In order to show that the large drops do not produce the interference rings, we may contrive to make a hair take up a comparatively large drop of water, or we may bring some of the small drops together so as to form larger ones. Now, upon examining those whose diameters are greater than about $\frac{1}{25}$ of an inch, we can perceive that they form beautiful bows, both primary and secondary, but in each case without any trace of supernumerary rings. In these drops, also, it is seen that there is "a continued diffusion of fainter light within the bright termination which forms the rainbow," and the colours of the latter are more brilliant and homogeneous than those formed in the small drops, especially the red, which is strikingly distinct at the edge. The limit of size beyond which interference does not take place may be determined by subjecting one of the large drops to a gentle evaporation. For this purpose the heat of the sun, in summer, will be sufficient. As soon as the diameter of the drop is decreased below the assigned quantity the supernumerary rings will be formed, being at first very narrow, though in great numbers, and they will continue to be produced at all smaller sizes. Upon examining various dimensions of the drop, we observe that the nearer its diameter approaches the limit referred to the more numerous are the rings, but the smaller sizes cause the colours to be broader. Also, as the size of the drop decreases, the colours produced are somewhat blended, the red of the principal bows appearing partly orange or yellowish even at the edge, and the supernumerary colours becoming yellowish and dark purple. When the drop is still further diminished, the primitive bows are exactly similar to the others, consisting of two colours only, and, before it finally vanishes, only bright and dark bands are produced.

The foregoing experiments may be made with other fluids, and it appears that the limiting diameter of the drop diminishes as the refractive power increases: thus it is less in oil of turpentine, linseed oil, &c., than in water. The rings are particularly brilliant and numerous in

oil. The principle might also be illustrated by melting small pieces of glass into globules of various sizes, and all the phenomena referred to can be seen in the dewdrops hanging from slender blades of grass, &c.

The diameter of the largest raindrop which can produce the supernumerary colours (estimating it without micrometrical appliances) is about $\frac{1}{25}$ of an inch; but from the general appearance of the bows it is probable that the drops which form them are much smaller. Dr. Young has calculated the size of those necessary to cause the phenomena described by Dr. Langwith to be about $\frac{1}{76}$ of an inch, and says it would be sufficient if they were between $\frac{1}{70}$ and $\frac{1}{80}$ (*Phil. Trans.*, vol. xciv., p. 48). It is certain that a slight difference in size does not interfere with the regularity of the bows; for, if we look into the web of a very minute spider, which, resembling gossamer, is to be met with on the ground, we can often perceive upon it drops of dew not exceeding $\frac{1}{1000}$ of an inch in diameter, and these collectively form several supernumerary rings, which appear perfectly regular and concentric with the outside bow, although it can scarcely happen that the drops should be exactly equal in size.

If the colours of the iris be seen through a telescope, as in M. Babinet's experiment, in which they are observed in a descending column of water let down through a small aperture, it is evident that the limit at which interference ceases to take place ought to be greater than when the phenomena are observed by the naked eye. Professor Potter, in detailing the results of his observations, mentions[2] that, when the water was $\frac{1}{10}$ of an inch in diameter, the interference bars were plainly visible, but in some other instances they did not appear at all. He has not stated the cause of their non-appearance, but it was probably owing to the thickness of the column of water exceeding the limit at which interference occurs.

Dr. Pemberton, in endeavouring to explain why the supernumerary colours usually appear more vivid under the upper part of the bow, remarks that "it is most likely they are formed in the vapour of the cloud which the air, being put in motion by the fall of the rain, may carry down along with the large drops,"[3] but it being certain that the clouds produce no such colours, we should rather attribute the circumstance to the greater abundance of the small drops in the higher regions, their number being diminished as they descend, on account of several particles coalescing with one another, and forming drops too large to produce colours by interference. It is also very probable that the unusual vividness of these bows, which occasionally occurs, is owing to the preponderance of small drops in the shower which produces them, and to their general uniformity in size. It may seem inconsistent with this explanation, that the additional colours often

[2] *Philosophical Magazine*, May, 1855, p. 321.
[3] *Philosophical Transactions*, abridged, vol. vi., p. 140.

appear very vivid in heavy rains consisting of large drops, but this circumstance is easily accounted for. In some of the heaviest showers which I have seen, when the rain was carefully observed falling between the eye and an aperture in a wall, &c., behind which a dark screen was placed, there could be plainly noticed, amongst the large drops, a great number of small ones, which, being impeded by the air, did not descend with the velocity of the others. These small drops may also be occasionally observed in the open air, when the heavy drops, descending in oblique lines, are crossed nearly horizontally by a multitude of spherules wafted by the wind in various directions. It is then these minute particles, which, being present in every shower, produce, when more or less uniform in dimensions, the colours of the supernumerary bows.

It would appear, from Dr. Young's theory, that in the iris formed by very small drops there ought to be a dark space between the primitive and supernumerary rings; but however small may be the particles which we examine, these colours lie close to one another, unless, indeed, the primitive bows be supposed to have vanished, and that all the rings are "spurious," being produced by rays of unequal lengths. This theory, also, does not explain the fact which appears to be well established, that the ordinary rainbow actually occurs within the calculated place of the caustic; neither does it explain the mixing of the colours at the outer edge of the bow produced by the small drops, which circumstance, taken in connexion with the diminished intensity of the light, would seem to indicate that, in this case, the rays of equal lengths have, at least, partially disappeared, although manifestly this does not take place in the large drops.

NOTE ADDED IN THE PRESS.

The phenomena here described are those which are seen in globular drops; but as small particles of water adhering to a hair are generally distorted into a spheroidal form, the bows produced by them are somewhat different in figure. Also, if the hair does not pass through the centre of the drop, one of the bows is sometimes absent, or is divided into branches. The large drops are not sensibly distorted; and on this account, when I first perceived that they did not form additional rings, I considered that the production of the latter might be a consequence of the spheroidal figure of the small drops: repeated experiments, however, convinced me that such could not be the case, and that the different appearances observed in both cases were entirely dependent on the size of the particles.

XXXIII.—SEA-BEACHES, ESPECIALLY THOSE OF WEXFORD AND WICKLOW. By G. H. KINAHAN. (With Plates 4, 5, 6, 7.)

[Read January 27, 1879.]

THE travelling of sea-beaches is a very interesting subject to the geologist, but it is one most important to the engineer, as it affects so strongly the questions of the proper positions and construction of harbours, piers, and groynes. During the time I have been engaged on the Geological Survey of Ireland (over twenty years) I have had, when stationed in maritime districts, favourable opportunities of observing the sea-beaches. This has been specially so during the last six years, while I have been engaged in examining the counties of Wicklow and Wexford, and in those years the observations made were both numerous and minute.

From the Papers read before the different Scientific Societies it would appear that two of the principal points of controversy as regards this subject are :—Whether are the wind waves or the tidal currents the principal moving agents in the shifting of the beaches? and—Can large stones be carried by somewhat ordinary ocean currents in deep water? To these subjects I have also paid special attention.

I propose laying before the Academy the results of my observations, which relate to :—

I. The travelling of beaches due to the tidal currents.
II. The effects of the wind waves.
III. Carriage of stones in deep water.
IV. The effects of the travelling of beaches on the harbours and piers between Hook Point (Admiralty Chart, Ireland, sheet xiv.) and Dalkey Island (Admiralty Chart, sheet xvi.); concluding with
V. A discussion of the groynes on the coast-line between Hook Point and Dalkey Island.

I. *Travelling of Beaches due to the Tidal Currents.*

This Paper will more especially refer to the observations made on the coast-line of south-east Ireland included in the Admiralty Charts, Ireland, sheets xiv., xv., and xvi.[1] On the accompanying map (Plate 4) the principal on-shore flow-tide currents have been indicated; those going with the course of the tide, the counter-currents (counter-tides), and the half-counter-tides.

As pointed out in Haughton's *Manual of Tides and Tidal Cur-*

[1] Sheet xv. is on the scale of two inches to the mile. The chart on the scale of one inch cannot now be procured; while the other charts, on the larger scale, have not as yet been published.

rents, the wave of the "flow-tide" coming in from the Atlantic strikes the west coast of Ireland, and divides, part going northward round the north coast, and part eastward, along the south coast, until it has passed Carnsore Point, where it enters the Irish Sea and flows northward until it meets the north wave, in the vicinity of the Isle of Man. These waves form, in places, on-shore currents; and the most conspicuous of those on the coast-line which we are now considering are as follows:—When the south wave passes Hook Point it sends a branch to the N.E., along the east shore of the Hook promontory to Bannow Bay, where, at the Keragh Islands, it is met by a "counter-tide." West and east of the Saltee Islands there are also two branch on-shore currents. The western Saltee current runs north-eastward to Kilmore Pier, where it turns westward and forms the "counter-tide" that meets the Hook current at the Keragh Islands. At the meeting of these two currents a shoal has accumulated. Under ordinary circumstances the current from Hook carries the beach with it only to the neighbourhood of Keragh, as proved by the fact that the stones from the Hook promontory are rarely found beyond Keragh. The "counter-tide" west of Kilmore carries the beach N.W. along Ballyteige Bay; and during the last forty years[2] (since the Ordnance Maps were made) has lengthened the Ballyteige sandhills more than two hundred feet.

The eastern Saltee on-shore current flows first N.E. and then eastward along the coast to Carnsore Point, during two-thirds of the "flow-tide"; but during the last two hours of the "flow"[3] there is a "half counter-tide" setting westward from Carnsore to the Kilturk Bank. The driftage towards the N.E., due to both the western and eastern Saltee currents, forms, at their colliding, long ridges called St. Patrick's Bridges, between the two Saltees and between the north Saltee and the mainland; while the meeting of the driftage due to the east current and to the "half counter-tide" from Carnsore have formed the Kilturk Bank.

In the Irish Sea the on-shore current runs north from Carnsore to Greenore,[4] where three currents, at least, are produced; one going north along the east margin of the Long Bank, the second in the channel to the west of the Long Bank, while the third sweeps round the shore of the South or Ballygeary Bay. The first or east current carries fragments of the Greenore and Carnsore rocks and other detritus to the Long Bank, and from it north-eastward to the Blackwater Bank, and from the latter to the "Shingle Beach," Cahore,

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[2] Here and elsewhere forty years is mentioned, as it was about that time the Ordnance Survey Maps were published. Prior to them there are no authentic records of the coast-line.

[3] This is an average, as the "half counter-tide" begins sooner during "springs" than in "neaps."

[4] The Greenore mentioned in this Paper is in the County of Wexford, and must not be confounded with the Greenore to the north (County of Louth).

and thence still further northward along the Wexford and Wicklow beaches; those fragments having been traced to Greystones, a little south of Bray Head. The second or middle current also carries fragments of the Greenore and Carnsore rocks northward in seven fathoms water, as has been proved by Thos. Winder, M. Inst. C.E., the Resident Engineer of the Ballygeary Pier, while making a submarine survey in connexion with the works; and the third or on-shore current carries similar fragments along the beach westward and afterwards northward.

The detritus carried by the second and third currents goes to the Dogger Bank[5] off the mouth of Wexford Harbour. From this bank some of the smaller stones are carried along the south or Hantoon channel into the harbour, and lodged on the western side of the Rosslare Bank; while the rest of these are swept N.E. across the deep water to the Blackwater Bank. Few or none of them seem to be carried across the North Channel into the North Bay; for, during my numerous visits to that bay, scarcely a fragment of the Greenore or Carnsore rocks was found along its beach; and when found they were only to the northward, in the vicinity of the south end of the Cahore "Shingle Beach." This accumulation of shingle is described further on.

The water of the lagoon causes various complications off the mouth of Wexford Harbour, as the tide within the lagoon flows and ebbs after the changes of the tide outside. In the early period of the outside "flow-tide," the northward current along the Raven and the Blackwater cliffs seems due to the efflux from the lagoon, but afterwards to a "flow-tide" current. There are alterations in the currents due to the changes of the Dogger Bank, but these changes are in part due to the wind waves.

The Cahore Shingle Beach is about three miles long, and is largely composed of fragments of the Greenore and Carnsore rocks; with these there are others from the cliffs along the Blackwater coast. From Cahore Point, during the latter part of the "flow-tide," a "half counter-tide" runs towards the S. W., which keeps back the "Shingle Beach," and prevents it from approaching within half a mile of the Point.

Opposite Courtown (north of Cahore) is the "nodal" or "hinge line" of the tides in the south portion of the Irish sea, where the rise is least and the current greatest. The on-shore current sweeps the coast line from Cahore to Kilmichael Point; but off the latter it is met by a "counter-tide," the meeting and colliding of the two forming the "Kilmichael Race," which extends from the Point to off the north end of the Glassgorman Bank. The refuse from the shipping at Courtown Harbour, such as bits of brick, tile, slate, coal, &c., are principally stranded along the beach a few miles S.W. of Kilmichael

[5] This Dogger Bank must not be confounded with the bank in the German Ocean.

Point. On this beach Greenore and Carnsore rock fragments are not uncommon; but in the two small bays to the north of the Point, the gravel and shingle is made up almost solely of the local rocks, many of the fragments being more or less angular. In connexion with these two bays are interesting phenomena to be mentioned hereafter in connexion with the wind waves.

From Arklow to Wicklow Head the general driftage of the beaches is northward; but in connexion with most of the headlands there are "half counter-tides" for a few hours before high water, especially during springs.[6] The debris from the shipping at Arklow is principally beached on the strand S.W. of Mizen Head; off Wicklow Head there are short "counter-tides" forming two or more races, the principal one being Bride's Race.

North of Wicklow Head a current from the S.E. strikes the coast line at Six-mile-Point, and there divides, part going northward, but a considerable portion southward, to form the counter-tide that carries the beach with it towards Wicklow. To its meeting with a current from the south is due the just-mentioned Bride's Race. In connexion with Wicklow Head there is, before high water, a "half counter-tide" running east to Wicklow town, which prevents the "full" beach extending south-eastward to the head. The current going north from Six-mile-Point is deflected by the land drainage from The Breaches; and at the colliding of these, the "Breaches Shoal" has accumulated. North of The Breaches a current runs northward to opposite Delgany, where it is met by a "counter-tide," and in the dead water produced at their junction the Moulddich Bank has been formed.

Farther north a current from the south-eastward impinges on the coast near Greystones, a part going south to form the just-mentioned "counter-tide," and the rest northward to Bray Head, off which it is met by a "counter-tide," and at their meeting a race is formed.

To the north of Bray Head a current from the S.E. strikes the coast line at the tower No. 4, near the middle of Killiney Bay: here it divides, a part constituting the "counter-tide" that runs S., carrying the beach with it to Bray, and from thence running to Bray Head to form the previously-mentioned race. Here, as at Wicklow, there is a little before high water, a current running E. from the Head to the S. end of the strand, which prevents the "full" beach extending to the high ground of the hill. Another similarity between these two beaches is, that from tower No. 4 to Bray, and from Six-mile Point to Wicklow, the pebbles forming the beaches gradually

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[6] These currents seem to occur at every rocky headland immediately before high water, especially during springs. They are of such short duration that usually they pass unobserved—yet they are important, as to them is due that the beach is kept back from reaching to the Heads.

increase in size, and at the south end of both strands the beaches are principally shingle.[7] From tower No. 4 the beach in Killiney Bay travels northward with the current; but in the vicinity of Dalkey Island there is, a little before high water, a "half counter-tide" south-westward.

The "ebb-tide" waves flowing out of the lagoons and estuaries deepen the channels and cut away the beaches margining the narrows; but elsewhere on this coast line they do not affect the beaches, except in the vicinity of Courtown, where the average rise of tide is about three feet. Even here the travelling of the beach, which is solely due to the ebb-tide current, is very small, as it only continues for an hour or so during spring-tides.

II. *The Effects of the Wind Waves.*

The waves of this class that act on this coast are of two kinds, viz., "ground swells," or waves generated by storms in the Atlantic or the Channel, and the waves directly due to the winds blowing on the coast. Their effects are either to pile up and fill the beaches, or to cut them out.

The ordinary wind waves assist the "flow-tide" current if both waves are going in the same direction, or if the wind waves strike the beach at an acute angle; if they strike the beach at a right angle they fill it up, forming "fulls" and "storm beaches," while if they are running in a more or less opposite direction to the flow-tide they cut out the beach. As an example: Let the flow-tide current be from south to north on an east coast. If the wind is blowing from any point between S. and E., E.S.E. by E. the wind waves assist the tidal current; but if it is blowing any point between E.S.E by E. and E.N.E by E. strong, the wind waves will stop the travelling of the beach, and pile it up, forming "full" or "storm beaches;" while if the wind is coming from any point between E.N.E. by E. and N. a "cutting out tide" is the result. This cutting out is due to the "dancing waves," generated by the meeting of the tidal current and the wind waves, which toss and churn up the sand and other detritus, thus causing it to be carried out by the back-wash into deep water. A continuous heavy wind in the same direction as the flow-tide will accelerate the carriage of a beach to such a degree that every particle of sand, gravel, and shingle may be carried with the tide, thus leaving the up-stream portion of a beach empty. These seem to be the general effects; but near Courtown, where the difference between low and high-water is

[7] In a Paper "On the Drifting power of tidal currents *versus* that of wind waves" (Proc. Royal Irish Academy, 2nd ser., vol. ii. p. 448), I have demonstrated that the reason why the larger pebbles occur down stream on some beaches is because the "back-wash" carries down and out to sea the small gravel and sand, leaving behind it on the slope of the beach the larger stones, which are pushed higher and carried farther along the beach by each successive wave.

only a few feet, and when the "ebb-tide" current is excessive, during heavy storm waves, the cutting out seems to continue for a little time into the ebb.

"Ground swells" act differently to the ordinary wind waves, as they break in on the coast line, perpendicularly or nearly so, with an undulating or rolling motion which generates a considerable "suck" or back-wash. The wind waves, which on one portion of a coast line assist the tidal current when this latter is flowing in a normal direction, may, on another portion, where there is a "counter-tide," act differently. This is exemplified in the embayment between Hook Promontory and the Saltee Islands. Here a gale from the S.W. assists the tidal current between the Hook and the Keragh Islands, and rapidly carries the beach to the N.E.; but the same gale striking the beach in "the bite" on the north of Crossfarnoge Point, to the east of Ballyteige Bay, where it is perpendicular to the tide current, forms a great "full", while along the Burrows to the north of this bay it meets the counter-tide obliquely, and cuts out the beach. Such winds also stop the seaward driftage of the shoal at Keragh Islands, thus causing great "fulls" in the strands at this part of the coast line, During such winds, at certain seasons, great masses of sea-wreck or drift seaweed are piled up in "the bite" to the north of Crossfarnoge. These weeds grow principally on the rocky bottoms adjoining the Saltee Islands, and during May and November, the seasons for the shedding of their leaves, the storms set the leaves afloat, and the tidal current carries them northward into Ballyteige Bay, where they are met and stopped by the storm waves and driven on shore at "the bite," to be stranded when the tide ebbs. Under ordinary circumstances the slope of the beach at "the bite" is less than 10°, and sometimes only 5°, but after a twenty-four hours' S.W. gale the slope often rises to over 35°. Three or four high tides, however, will reduce it nearly to its normal condition; the "full" being carried N.W. along the strand of the Burrows rapidly filling up what had been cut out by the gale.

Between the Saltees and Carnsore, S.E., and S. winds accelerate the travelling of the sands to the Kilturk Bank; but here they are met by the "half counter-tide," thus causing "fulls" in this locality. In this place, at the proper seasons, there is also a great stranding of sea-wreck. These weeds grow near the Saltees to the southward, and near Carnsore to the eastward, and are carried to this locality by the tidal current from the S. W., and by the "half counter-tide" from the E. Ordinarily the weed is beached on the coast at the small headland near Kilturk; but if, while it is floating, there is a gale from the S. E., a considerable quantity of it will be landed on the shore N.E. of Carnsore.

Observations in connexion with the "half counter-tide" running westward from Carnsore are instructive. In a gale from the S. W., during the first four hours of the "flow-tide," the beach travels rapidly towards Carnsore; but after the "half counter-tide" sets in,

the driftage is westward. This forms a "full" (*a*, Fig. 1, Pl. 5) on the slope of the beach, and gives the beach a lower (*b*) and an upper (*c*) slope, with a cess, as the Dutch engineers call it (*a c*), between; thus producing a section, of a form best calculated to break the force of the waves in the succeeding two hours of the full tide, which prevents the storm waves from having full effect on the coast line. Ordinarily, however, this beach is much cut out, especially by "ground swells;" and when the shores are empty, gales, whether from the S. W., S., or S. E., have great effect. Consequently, during the last forty years, the coast line between Lady's Island Lake and Kilmore has been considerably denuded away, especially in the vicinity of St. Patrick's Bridge. These beaches, during the continuous E. and N. E. winds of the spring of 1876, changed from their ordinary gravel into "fulls" of shingle. This must have been solely due to the "flow-tide" currents, as for months no wind waves broke on the coast.

On the east coast, between Greenore and Dalkey Island, as a general rule the beaches are travelling north, and this is accelerated by the south and south-east winds; there are, however, long stretches of beach swept by "counter-tides," at which places these winds generate "cutting-out tides." Although the most continuous winds are those from the S. W. and W. S. W., yet they are not effective winds, as they come across the land; their only effects being those due to the "ground swells" generated by them and the driftage seaward of the Æolian sands, so prevalent on the east coast line of Ireland. The winds that do the most damage on this coast are those from the S.W.; but the most continuous that effect the beaches are those from points between E. and N., and their results are perhaps the most interesting.

The points of interest in the South or Ballygeary Bay, N. W. of Greenore, will have to be mentioned hereafter when describing the harbours and groynes, so at present they may be passed over. In the North Bay all winds seem to "cut out," this being due to the complication of the tidal currents, the beaches rarely being full, except in the summer and autumn, when there are no winds. On account of the great cutting out along this beach, the marginal cliffs have been vastly denuded within the last forty years. The "Cahore Shingle Beach," at the north of the bay, is fullest during S. and S. E. gales; while it is cut out by winds from the N. E. and by "ground swells." After S. and S. W. gales it is often smothered up with fine sand, blown from the adjoining accumulations of Æolian drift.

A little N. W. of Cahore Point is Poulduff Pier, with the beaches accumulated since it was erected, while farther northward are the piers and other works at Courtown. These will be described hereafter; but it may now be mentioned that between Cahore and Kilmichael Points the driftage is nearly altogether northward, and accelerated by the S. and S. E. wind, while the N. to E. winds cut out the strands.

On the coast line S. (Fig. 4, Pl. 6) and N. (Fig. 5, Pl. 6) of Kilmichael Point there has been considerable denudation of the sandhills since the Ordnance Survey was made (forty years). In the first locality

over 37 acres have been carried away by gales from the S.E. Here there is an excessively swift tidal current to the N.N.E., which, under ordinary circumstances, carries all the beach with it, and leaves no protection between the sea and thesandhills; consequently, under these circumstances during S.E. gales the wind waves have full power on the latter, which they then rapidly denude away. As previously mentioned, off Kilmichael Point, to the N. E., is a "race," due to the meeting and colliding of the just-mentioned tidal current and a "counter-tide" coming from the northward; but the latter is affected by continuous winds from the north and north-eastward, prolonging it southward, and forcing the "counter-tide" round the Point into the bay to the south thereof. Consequently, under such circumstances these winds, instead of cutting out, form "fulls" for about a mile in the strands to the S.W. of Kilmichael Point, thus preserving the sandhills. The cross sections accompanying Fig. 4*a*, Pl. 6, show this beach to true scale. No. 1 represents the beach in June, 1875, when it was one continuous slope, up which the storm waves from the S. E. could rush with full force; while cross section No. 2 shows exactly the same line after continuous gales from the north-eastward, which had accumulated a wide foreshore that perfectly protected the sandhills from the S. E. gales.[8]

Northward of Kilmichael Point, in the bay at the mearing of the counties Wicklow and Wexford, the denudation of the sandhills has also been considerable within the last forty years (Fig. 4, Pl. 6), more than 20 acres in the townlands of Cloon, Lower and Upper, having been swept away. Here there is a "counter-tide" running S., and the wind from points between E. and N. accelerate the southward travelling of the beach, but E. winds cut it out. During none of my visits were the beaches "full," there being a gradual slope, up which the storm waves from the S. E. could run with full force, and impinge on the sandhills. According to the information supplied to me, the latter are only denuded by S. E. gales, these being most effective when the strand is empty.[9]

Farther northward are the beaches of the bays at Wicklow and Bray; it is here unnecessary to describe them further than to mention the "storm beaches." These peculiar ridges are very rare S. of Wicklow Head; in fact, on that portion of the coast they are so

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[8] This is a most remarkable place, as, in recent years, the sandhills at one time seem to be forming, and at others wasting away. Some of the old men can point out the extensions of the sandhills prior to the Ordnance Survey, and the roads that used to lead to them, which now end at steep cliffs; while one old man, in June, 1875, pointed out, in a cliff that had only been uncovered the previous winter, an old quarry that must have been worked with *iron* tools prior to the accumulation of the sandhills that existed when the Ordnance Survey was made.

[9] Although I visited this place frequently, I never had the satisfaction of finding the beach "full"; while the information I received was unsatisfactory, as the native said, "everything travels to the north." Yet I could prove by the carriage of the rock fragments, also by the experiments made at my different visits, that the beach travelled south during "flow tide" ("counter-tide").

indistinct, that no one unacquainted with such accumulations would observe them; but they are characteristic of the S. portion of the strands of Wicklow and Killiney Bays, always occurring in connexion with the "counter-tides." They are best developed during directly on-shore gales from the E. If formed during the rise of the spring tides, each ridge after being produced is destroyed by the next "flow-tide," but if formed during the fall of the springs, successive nearly parallel ridges accumulate (Fig. 2, Plate 5), which remain till the next spring, when they are levelled, and the material carried southward.[10]

It ought to be specially pointed out, that *the storms which cut out the beaches may not be the same as those which denude away the marginal cliffs.* The beaches are principally "cut out" by "ground swells," or storm waves, that come in an opposite, or obliquely opposite, direction to the "flow-tide" current, or they may be carried forward by the sole agency of the tidal current, or by the latter assisted by wind waves coming in a similar direction. Any of these causes may scoop out or sweep a strand bare, and leave it with little or no beach; and, under the latter circumstances, the storm waves act with full force on the marginal cliffs.[11] A small storm when the strand is empty may do great damage on the coast line; while a great storm with a full beach will do scarcely any. The best section of a beach seems to be that similar to Fig. 1, Plate 5, having below, or to seaward, a slope (*b*), above which is a flat or "cess" (*a*, *c*), and higher up a second slope (*c*), which is succeeded by a second "cess." Such beaches, however, seem to be of rare occurrence, they usually having cross sections similar to that in Fig. 4*a*, Pl. 6, with a slope below and a wide "cess" above; but on the "cess" in this case the waves lose a great deal of their power before they reach the marginal cliffs.

Extraordinary high tides, unaccompanied with wind, seem to do little or no damage on an open seaboard. In March, 1867, there was a remarkably high tide on the coast of Galway, the traces of which were scarcely perceptible along the open coast, even on the sandhills; but in the land-locked bays it did considerable damage to the piers

[10] On this portion of the Irish shore, where there is a tidal current, the "storm beaches" only exist during the intervals between the spring tides; but in other places, where there is a "rise" and "fall" of tide, but no currents, the "storm beaches" remain, and add to the extent of the land. The latter is very well seen in North Wales, along the coast line of Morecambe Bay, as also in other places.

[11] After very wet seasons great falls of the cliffs often take place; but until the debris is denuded away, few or no further falls will take place. The natives will often tell you that so many yards are going yearly, and in proof of this assertion will point to the waste of the previous winter, they supposing that the same happens every year. The greatest falls occur at the highest cliffs, on which account the greatest waste is supposed to be taking place in these localities; but after careful calculation I find this not to be the case. None of the high cliffs reach an average waste of ·75 ft. per annum, and generally the loss is less than ·5 ft., while in places the low cliffs have been denuded away as much as 2·5 feet per annum. The greatest denudation on the whole line of coast between Hook and Dalkey is at the low cliff near St. Patrick's Bridge, Kilmore.

and sea walls. This damage was not due to the direct force of the waves, but to other circumstances. In this county nearly all the piers and walls have vertical or nearly vertical faces, and at the time mentioned, on account of the greater height of the water, these faces caused waves to rise, that fell on and behind the piers, thus removing the coping stones, and in places breaking the structures. In some places the sea walls were similarly injured, while in others the water flowing over the walls cut away the backing, and gradually cut out breaches from the inside to the outside.

On January 3, 1877, there was on the east coast a very high tide, which along the Wicklow coast was accompanied by very moderate wind.[12] This did considerable damage to the Dublin and Wicklow Railway between Greystones and Wicklow; not so much by the direct force of the waves as by their height, they flowing over the line, and the overflow cutting into the land side of the embankment, thus gradually eating out the breaches. In no place did a breach commence at the outside.[13] This tide did not cause a "full" of the beach, although it pushed the margin higher and more inland than formerly. Between Newcastle and the Wicklow Chemical Works it encroached, in places, as much as three yards, into the Murrough (*anglice* sea plain); and the beach after the tide presented a gradual slope, having shingle and gravel to the margin of the old beach with fine sand in the new portion. Elsewhere along the east coast of Wicklow and Wexford this high tide did little damage. It invaded kitchen middens and such like accumulations in the vicinity of the towns, and floated out vast numbers of bottle corks, which in all cases were carried northward by the "flow" and stranded along the margin of the full tide.

During the last six years various experiments were made during the different stages of the tide, while the wind was blowing in different directions, as also when "ground swells" were coming in, to test the travelling of the beach, and also to discover what caused the "cutting out" of the beaches, and their filling in with white quartz pebbles about the size of hen eggs. The effects of each wave were noted; these, of course, cannot now be described in detail; we shall give only the general conclusions arrived at in regard to this portion of the east coast. We cannot do the same for the coast between Carnsore and the Hook, as the "counter-tides" there cause so many complications.

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[12] At Kingstown Pier, Co. Dublin, the wind was from the east at 8 A.M., with a force of 7, and veered to the S. S. E. by 6 P.M., gradually falling to a force of ·3.

[13] This nearly always is the cause of breaches in the steep-faced embankments so general in Ireland to protect the different intakes; they all fail from the water topping them and breaching them behind.

Summary of the General Effects of Tides and Winds on the East Coast between Carnsore and Dalkey.

W. and S.W. Winds
generate "ground swells." In places they drift the sand from the land out to sea, and on to the beaches.

S. Winds
in places cause "fulls" at the northern extremities of the strands, due partly to the banking up of the beach, and partly to the land driftage of sand. They often generate "ground swells."

S.E. Winds
carry away the southern end of the beaches, to fill them in at the northern. At Poulduff (Cahore), two strong twelve-hour gales are said to be sufficient to cut out the "fulls" south and north of the pier.

E.S.E. by E. to E.N.E. by E.
generally heap up the beaches. In places, however, on account of coming obliquely to the flow-tide current, they in part cut them out, forming transverse ridges on the beach, Fig. 4, Pl. 5. The first drives up sand, gravel, and stones, and strands them; while the second "licks" them out. To form this class of beach the wind waves are not as effective as the tidal currents, and the materials are more stranded than removed; so that while the wind lasts the strand fills.

N.E. Winds
cut out the northern portions of the strands, while they often "fill" the beach to the southward. The most remarkable "fulls" due to these winds are the previously-mentioned "fulls" to the S.W. of Kilmichael Point, the "fulls" in the strand near Wicklow, and in the strand near Bray. In the first locality, after the continuous winds from the north-eastward during the spring of 1876, a foreshore formed, in places over 200 yards wide, at the base of a cliff, where, during the previous winter, there was deep water.

N. Winds.
No direct influence of these winds was observed, except that they seemed to retard the flow of the tide up the Irish Sea.

Ground swells,
with the "flow-tide," usually "cut out." They sometimes form transversely-ridged beaches similar to those due to E. winds (Fig. 4, Pl. 5); but in such cases the cutting out is generally in excess.

At the beginning of the "ebb-tide," sometimes "cut out," especially near Courtown.

Ground swells—*continued.*

With E. winds, sometimes seem to assist in filling the beaches, but with N.E. winds they "cut out."

With the "counter-tides," "cut out" the beaches.

With the "half counter-tides," sometimes "fill in" the beaches.

The cutting out due to "ground swells" and contrary winds is different from that due to the S.E. winds; as the latter carry the beach forward, while the other suck out the beach into deep water. "Ground swells" due to S. winds break on the shore line nearly as quickly as ordinary wind waves; but the waves of the other "ground swells" have intervals of one, two, five, or more minutes between them; the latter are much larger than the wind or tidal waves, which may be breaking at the same time, rise much higher on the beach, and often at one sweep carry away a mass of material that it has taken a number of the small waves to pile up. Some of the big waves, or "rollers," that visit the coast on rare occasions, are due to earthquakes.

III. *The Carriage of large Stones in Deep Water.*

On the coast of Galway, in many of the small bays or strands, are beaches composed of very large, roundish shingle, many of the blocks weighing two or three cwt. and a few over a quarter of a ton. These beaches were found to be fuller after storms than at other times; many of the blocks were derived from rocks situated more or less to the southward of the beaches, and those blocks, in order to reach the positions in which they were, must have travelled through water fifteen or more fathoms deep. As, after storms, laminaria and other deep-water seaweeds were observed to be attached to the blocks most recently brought in, a series of observations were made during the calms. It was ascertained that, in places both in the bays and in the open sea, in water from twenty fathoms deep to low water of spring tides, there are variously-sized blocks scattered about irregularly on sandy bottoms; and on these seaweeds grow rapidly, some having leaves whose measured lengths were over twenty feet. It was also found that, when the leaves were full grown, the weeds made the stones buoyant; in some cases so much so that they were, during each "flow-tide," drifted from their places towards the shore. By other observations it was found that places which had been dotted over with stones, with sea weeds attached, were after storms free from them. This was ascertained by marking favourable spots on the chart, and visiting them as soon as possible, during low water, after a storm. Some of these stations were four miles from the coast line.

Mr. J. Chaloner Smith, M. Inst. C.E., pointed out to me a sandy strand, below the south end of the Bray shingle beach, which was supposed to be always free from blocks. Circumstances prevented me from making observations here, therefore I turned my attention to

a similarly circumstanced sandy strand at the west end of the Tacumshin Æolian sand ridges (Chart sheet, xiv.), which was visited during low water on April 4, 1876, after a heavy gale from the S.W. Section (Plate 5, Fig. 3) represents the form of the beach. Below, at the line of low water, there was nearly level, undisturbed fine sand; next above this was a slope of shingle, mixed with gravel and sand. At A and B, above and below the shingle slope, were lines of blocks with deep-seaweeds attached to them, and a few similar blocks were scattered over the slope, while they were very numerous on the nearly flat undisturbed sand, between B and C. As the tide rose, the blocks to which seaweed was attached began to travel landwards, although there was no wind, and only slight waves, due to a "ground swell." When visited twenty-four hours afterwards, not a block remained on the fine sand, and only a few on the shingle slope, they having been collected into horizontal lines at A and B. Subsequently this beach, as also others similarly circumstanced, were visited after storms, and in all cases the results were the same; as the large stones attached to deep-seaweeds were brought in, and in one or two tides sorted and arranged in lines, below and above the slope of the beach.

When discussing this subject with Mr. Thos. Winder, M. Inst. C.E., he mentioned that after he had ran out the Dover Breakwater into ten fathoms water, "pebbles, during storms, were carried round it, foundations opened were filled with sand and gravel, the pebbles usually not being larger than nuts, but sometimes as large as hen eggs; while rounded chalk flints, from the Shakespeare Cliff, were carried to the end of the breakwater"; also that a piece of iron plant, about 1·5 feet by 2 feet, and 1·5 inches thick, was, during a gale, blown off the stage, and carried about twenty feet to leeward, or about thirty feet from the end of the work, in water about ten fathoms deep. "I traced the track of it through the small thread-like seaweed, and my conclusions, as I stood on the sea-bed, were that the sea undoubtedly moves things which may fall upon, and stand above, the general sea-bed in depths of ten fathoms; although it does not move the fine and tender growth which my feet trod into the surface, and my hands easily pulled out of it."

During storms large stones, with deep-seaweed attached, are carried up on to St. Patrick's Bridge, near Kilmore, county Wexford, as also on to the tidal portion of the Long Bank off Ballygeary Bay. At the Kish Bank, off Dublin Bay, an attempt was made to erect a lighthouse on screw piles; but it was given up, as the flanges of the piles were broken by large blocks in the accumulation of sand. Such blocks were probably carried by seaweed to this shoal, as the shifting nature of which shows that it is the result of the action of the present sea, and not a submerged hill of boulder drift.

From the foregoing observations it would appear that large blocks can be drifted in considerable depths of water: not by the simple impulse of the currents or storm waves, applied directly to them, but by

that action, combined with the buoyancy given to the stones by the growth of the seaweed on them. Tidal currents of great depth, if there is sufficient weed attached to a stone, would, although slowly, yet gradually carry it into water of a sufficient depth to be influenced by storm waves, after which the driftage would be accelerated. In some cases I have observed that the buoyancy of the weeds attached was superior to the weight of small stones, and that the latter, when lifted from their sand bed, were at the mercy of the currents. Thus any stone, no matter what its size, if the buoyancy of the weeds attached exceeded its weight, may be drifted by a tidal current in any direction, no matter what depth the water between the place from which it first started to that at which it was finally stranded. In connexion with the growth of seaweed, it may be mentioned that at the Ballygeary pier, during the time the works were discontinued in 1877 till the resumption of operations in 1878, the divers found the foundations (consisting of bags of concrete), laid down the previous year, "overgrown by a thick forest of seaweed over eight feet in height."

IV.—*The Effects of the Travelling of the Beaches on the Harbours and Piers between Hook Point and Dalkey Island.*

The principal piers and harbours on the coast line between Hook Point and Dalkey Island are those at Kilmore, Ballygeary, Wexford, Poulduff (Cahore), Courtown, Arklow, Wicklow, Greystones, and Bray. All of these, except those at Wicklow and Greystones, are unsatisfactory on account of the driftage of the beaches, in addition to which there is at Courtown and Arklow the land sand driftage. The present state of these different harbours and piers seems due to there having been no allowance made for the travelling and the stoppage thereat of the beaches under the influence of the tidal currents and wind waves. Their condition suggests that in all such constructions, if it is possible to avoid it, no impediments should be placed in the line in which the beach naturally travels; also that the piers ought to be perpendicular to the coast line, and not curved; as those of the first class act similar to the headlands, and generate a "half counter-tide" a few hours before high water, which keeps sand from accumulating alongside them.

Kilmore Quay.—This is situated on the South Wexford coast, about half way between St. Patrick's Bridge and Crossfarnoge Point (Fig. 1, Pl. 6). The harbour is sheltered by the pier from the W. and S. W. winds, but it is open to S. E. and E. winds, and when these blow strongly the fishing boats have to be drawn into the "old boat harbour." The "flow-tide" driftage goes N. E. from the Saltees to the St. Patrick's Bridge, and from thence westward to Crossfarnoge; and, being stopped by the pier, it is rapidly silting up the harbour. The driftage of the beaches and the direction of the more prevalent and destructive winds being as described above, it would appear that the most advantageous situation for the quay would have been on St. Patrick's Bridge; while to protect the harbour from the S. and S. W.

winds a breakwater could have been erected in the strait between Crossfarnoge and the North Saltee. Such structures would have constituted a harbour protected from all bad winds, and at the same time would not have presented any obstacles to the free driftage past of the sands and beaches.

BALLYGEARY SHIP PIER.—This is now in course of erection. It is to consist of a pier in deep water, which is to be connected with the land by a viaduct. The shipping will have harbourage on the east side of the pier, while the beach can drift past under the viaduct and thence westward along the shore line. When it was commenced, a short land pier was run out to low water of spring tide, from which the viaduct should start: this land pier, however, acted as a groyne, and the small embayment to the east rapidly filled up. To this we will return hereafter in connexion with the description of groynes.

WEXFORD HARBOUR.—The shifting sands at the entrance into Wexford Harbour have been, from time immemorial, a source of annoyance and expense to the inhabitants of the town; but as that eminent engineer Sir John Coade, M. Inst. C. E., has lately reported on them, it would be presumptuous in me to make any remarks or suggestions about them.

POULDUFF QUAY (Cahore).—This was built for the convenience of the boats during the herring fishing, and for landing the cargoes of vessels during calm weather. It is a pier running out at right angles to the beach, and having in the centre of it a culvert to carry off the drainage from the Cahore flats; while at a little distance from the end of the pier, and connected to it by a wooden bridge, is a short breakwater (Fig. 2, Pl. 6). This has been a complete failure in every way, as north and south of the pier great "fulls" have collected, which not only prevent boats approaching the pier, but also have stopped the mouth of the culvert. As previously mentioned, the driftage south of Cahore Point moves northward, and after it passes the point it turns westward into the Poulduff beach, where it is stopped by the pier. N. E. winds cut the "full" to the north of the pier, but they are prevented from acting on the south "full" by that structure; and as long as the south "full" remains, the pier continues banked up; for as fast as the north "full" is cut out it is replenished from the south one. This pier is never clear, except after a storm from the S. E., which has caused both the south and north "fulls" to travel rapidly northward.

When the conditions of this locality are considered, it would appear that when the pier was first contemplated the site chosen for it ought to have been near Cahore Point. If it had been erected there it would not have interfered with the present driftage, while it would have given shelter to the boats from the S. and S.E. winds. Under present circumstances, the pier might be greatly improved by securing and making permanent the south "full." This could be

effected by piling, or a concrete wall along its margin.[14] If this were done, the north "full" ought soon to be carried away by the tidal driftage and the cutting out of the N. E. winds.

Courtown Harbour.—This has not been a successful undertaking. The work consists of two parallel piers leading to a small basin, into which the Owenavorragh has been conducted by a canal cut from Courtown House (Fig. 3, Pl. 6). Within and near the mouth of the harbour a bar accumulates, over which it is both difficult and dangerous to haul the boats except in calm weather.

None of the conditions of the locality seem to have been considered in laying out this harbour. As at Poulduff, so here also, the most advantageous site would have been near the point (Breanoge Head); besides, the two piers should not have been of equal length: it is in consequence of their being so that the nearly impassable bar is formed. The driftage and cutting out of the beach is similar to that at Poulduff, but the N. E. winds have little or no power between the piers to cut out the bar.[15]

There seem to be facilities for constructing, even under present circumstances, a good harbour in this locality for a coasting trade. But to do this the south "full" would have to be secured and made permanent by a retaining wall from Breanoge Head to the south pier: the latter should be lengthened into deep water by a stage similar to, but higher than, that which is now in ruins; while the north pier ought to be cut away, and the land driftage from the sandhill to the north prevented by a wall or trees. The retaining wall from Breanoge Head would prevent detritus accumulating on the south of the piers, to be carried by every "flow-tide" into the harbour mouth. A stage instead of a solid pier would not interfere with the driftage, while the cutting away of the north pier would give the N. E. winds full power of cutting out any bar that might accumulate.

Arklow Harbour is circumstanced somewhat similarly to Courtown Harbour. I hope to describe it fully elsewhere.

Wicklow and Greystones Harbours.—At these localities the observations made were not sufficient to be of much value. At Wicklow the shingle beach does not travel far enough south to block the entrance. This seems to be due to the "half counter-tide" previously mentioned, which a few hours before high water runs from Bride's Head westward. It might have been expected, that as the head waters of the Vartry, which river here flows into the sea, were cut off some years ago to supply Dublin with water, some alteration would have since taken place in the condition of the bar at Wicklow

[14] Piling fails on this coast on account of the worm; it is therefore not to be recommended.

[15] Some years ago the end of the north pier was carried away by a storm, and while it was in ruins the bar diminished, but since the pier was repaired the bar has been as bad as ever.

Harbour. Yet, as I have been informed, the river bar has not perceptibly changed since that time.

Bray Harbour has met with various disasters, which I have described in a Paper read before the Institute of Civil Engineers, Ireland.

V. *The Groynes on the Coast Line between Hook and Dalkey.*

ON no coast line are groynes so necessary as in that now under consideration, especially in parts of Wexford and Dublin where valuable land is yearly disappearing; yet they have been erected only in isolated spots.

Near Tacumshin Lake, on the south coast of Wexford, two small systems of groynes were made, to stop the inroads of the sea. These consist of a lateral barrier, from which short groynes extend to a little below high water-mark. These were most effective; the lateral barrier and the upper portions of the groynes stopping the land driftage of the Æolian sand, while the lower portion of the groynes pounded up the shingle beach: permanent ramparts are the result.

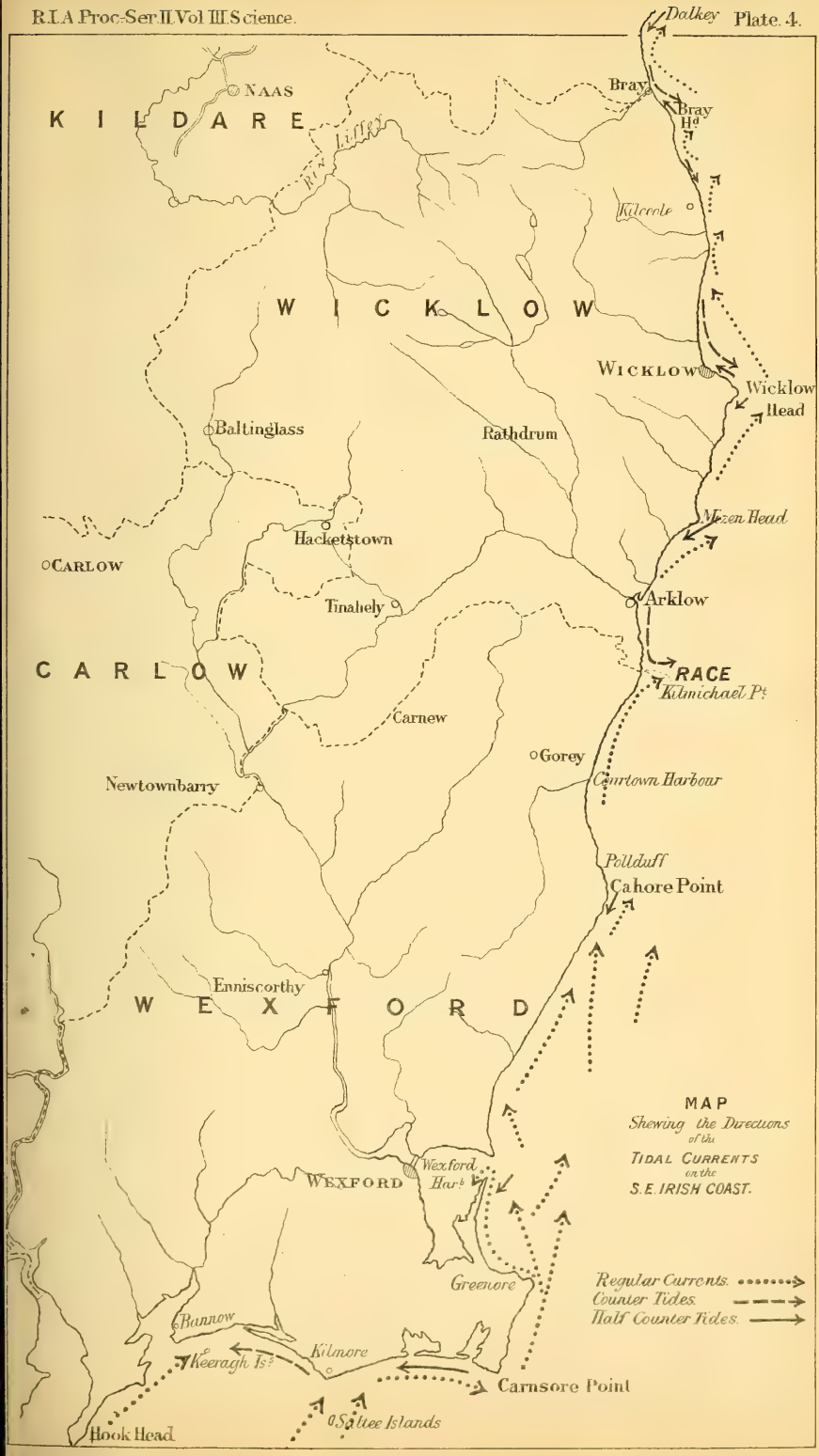
The landward portion of the Ballygeary Pier, although not intended as a groyne, has acted as such, and is an accidental proof of what great benefit would be derived from the construction of groynes on this coast line. In 1873, and previous years before the pier was commenced, "fulls" were formed on the beach line between Greenore and Rosslare Coastguard Station after continuous E. and N. E. winds; while at other times the "flow-tide" current sweeps the rocks clean at the base of the marl cliffs, thus leaving the latter open to the full force of the storm waves. In the spring of 1875, "fulls" accumulated between Greenore and the new pier during the E. and N. E. winds; and since then these have not been cut out, but, on the contrary, are gradually increasing. The small embayment to the east of the pier has been quite filled up, and now "sand-dunes" are gradually growing on it; while farther S. E. the rock section is almost concealed, and the denudation of the marginal marl cliff is gradually ceasing. This pier, or groyne, seems also to have had a beneficial effect on the marl cliffs to the westward of it. For, although the strands at the base of those cliffs appear very little fuller than formerly, yet their denudation seems to be gradually decreasing.

Here we may also mention other accidentally-formed groynes in the same neighbourhood. Formerly the *alva marina* was in great request, and the weed was carefully gathered. About the year 1876 the trade fell off, and the ungathered weed was carried by the tide and lodged in masses along the east end of the embankment of the North intake in Wexford Harbour. Previously to this the sea was cutting out and endangering the stability of the embankment, but the mass of seaweed formed a groyne against which masses of sand have since accumulated. In the winter of 1872–3 numerous large balks of drift timber were stranded on the Wexford coast. One of

these, a little south of the Blackwater, was floated in, during a spring tide, against the cliff, where it was fastened by a chain and left for over six months. During the time it was allowed to remain the land driftage collected against it a mass of Æolian sand, which has since become permanent, and has stopped the denudation of the cliff-line. Slips of the cliffs also form groynes, but only temporarily, as they are gradually cut away by the sea. Poulduff, Courtown, and Arklow piers have also acted as groynes, and to the southward of each of these are now considerable permanent accumulations.

On the coast of Wicklow, between the Kilcoole railway station and The Breaches, very effective groynes were constructed. These were erected under peculiar circumstances. The "flow-tide" current was rapidly cutting away the beach and endangering the railway; while the Company were restricted from making any works outside their boundary, a width of less than six yards, and any groynes placed inside such limits would extend only a short distance below high water-mark. They were, however, erected, the principal ones being over six feet high; and, although the circumstances seemed to be unfavourable, they filled rapidly, and formed a rampart that has stopped the encroachment of the sea.

At the north end of the Esplanade at Bray there is a system of groynes; but various circumstances have combined to make them ineffective. Their site was only a short distance south of the channel out of Bray Harbour; and the water from the river and estuary cut off the southward driftage of the beach to them, carrying it seaward, while the detritus that was beached on the south of the harbour channel was immediately carted away; thus much of the materials that should have filled the groynes never reached them. In addition to this, the groynes do not seem to have been judiciously planned or erected. They were constructed of round timber, driven down vertically; and in no place in Ireland have I found that round timber, driven down vertically, forms effective groynes. Furthermore, midway between the groynes extending from the coast-line, other short ones were placed, a little above low water-mark, and these generated currents which licked out all the shingle from between the land-groynes. The boundary pilings at the new baths on Bray Esplanade have acted as groynes, and have collected a considerable mass of shingle alongside of them.


Dalkey
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Hacketstown
Mizen Head
CARLOW
Tinahely
Arklow
CARLOW
RACE
Kilmichael Pt
Carnew
Gorey
Courtown Harbour
Newtownbarry
Polldhuff
Cahore Point
Enniscorthy
WEXFORD
Wexford Harb
WEXFORD
Greenore
Bannow
Keeragh Is
Kilmore
Carnsore Point
Saltee Islands
Hook Head
MAP
Shewing the Directions of the TIDAL CURRENTS on the S.E. IRISH COAST.
Regular Currents.
Counter Tides.
Half Counter Tides.

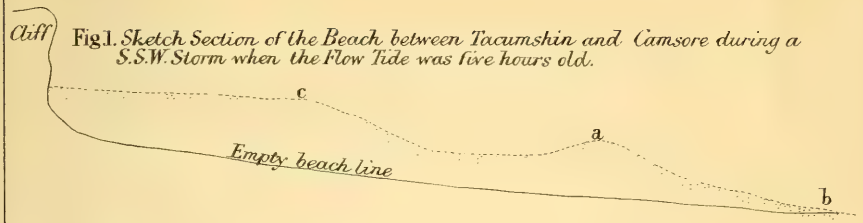


Fig 1. *Sketch Section of the Beach between Tacumshin and Camsore during a S.S.W. Storm when the Flow Tide was five hours old.*

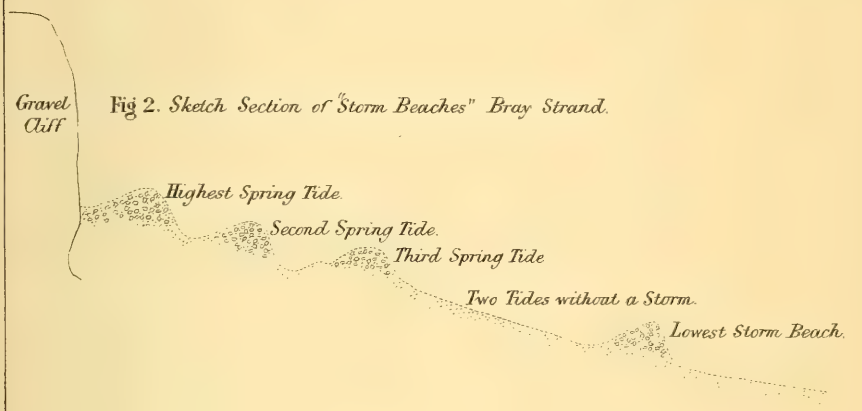


Fig 2. *Sketch Section of "Storm Beaches" Bray Strand.*

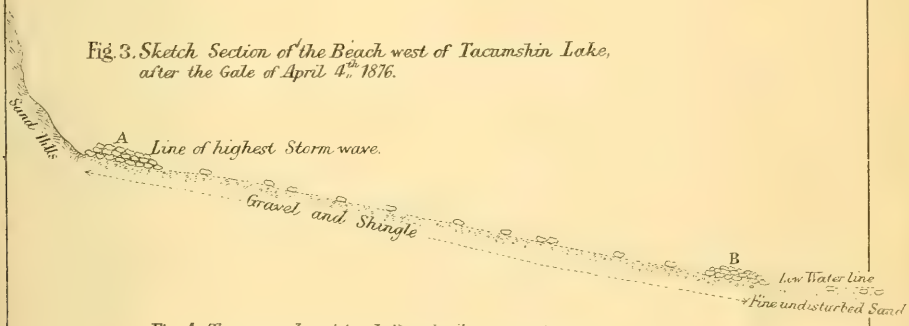


Fig. 3. *Sketch Section of the Beach west of Tacumshin Lake, after the Gale of April 4th 1876.*

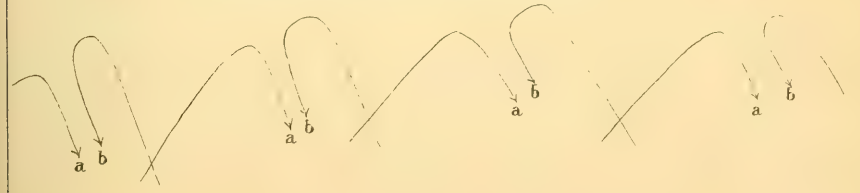
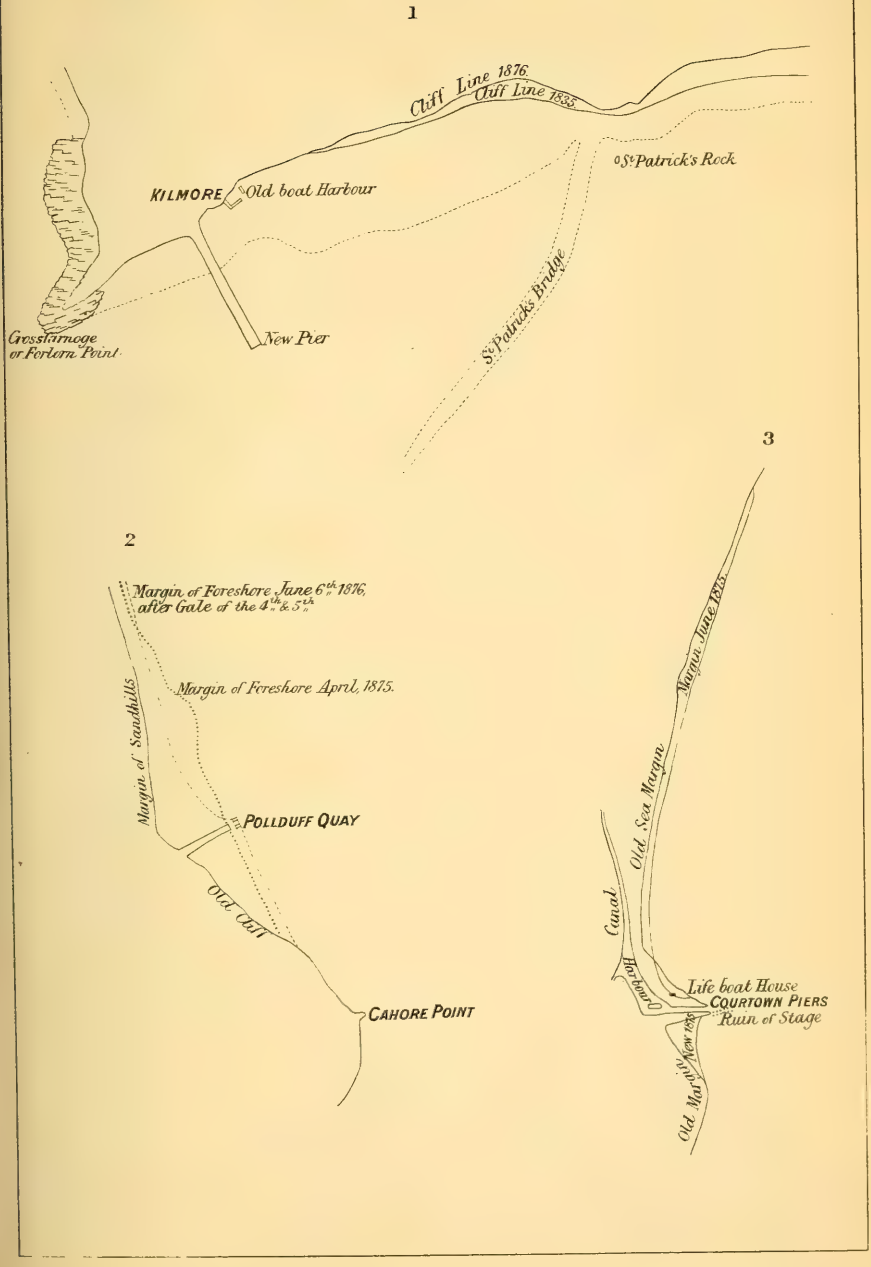
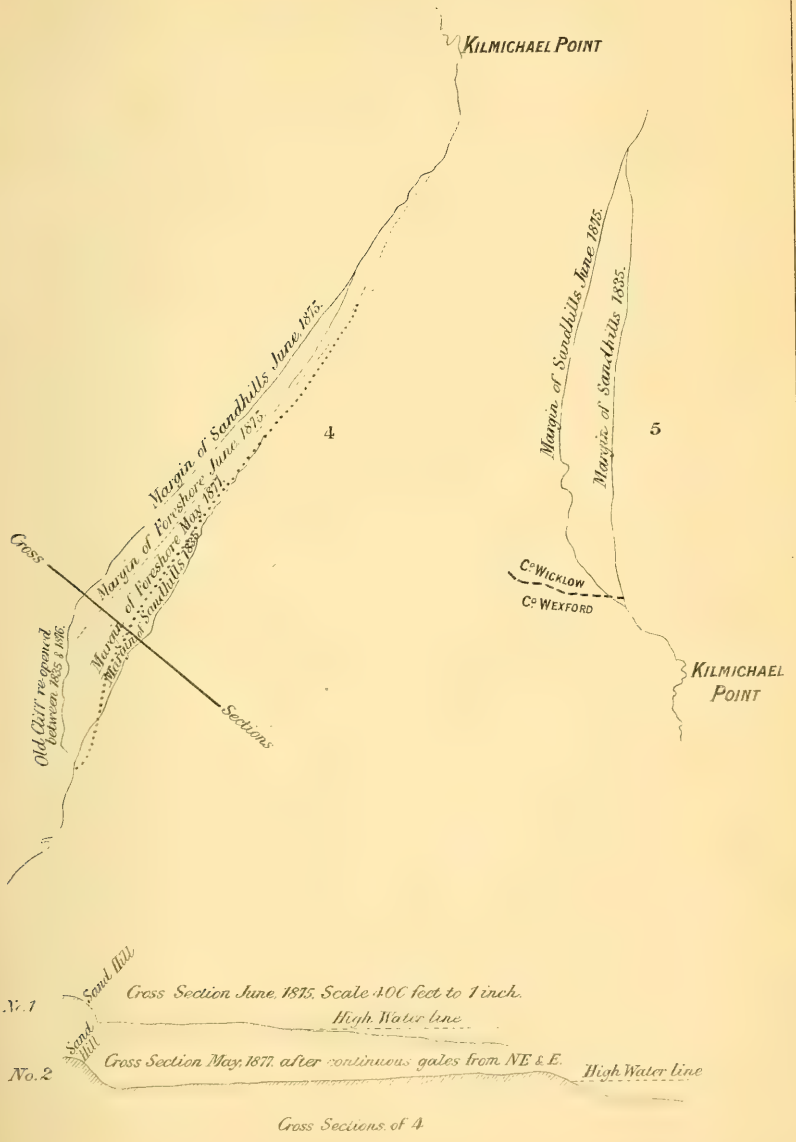


Fig. 4. *Transversely ridged Beach the curved arrows represent the rise and return of the different waves.*


1
Cliff Line 1876.
Cliff Line 1835.
KILMORE
Old boat Harbour
St Patrick's Rock
St Patrick's Bridge
New Pier
Grosstarnoge
or Fortern Point
2
Margin of Foreshore June 6th 1876,
after Gale of the 4th & 5th
Margin of Foreshore April, 1875.
Margin of Sandhills
POLLDUFF QUAY
Old Cliff
CAHORE POINT
3
Margin June 1835.
Old Sea Margin
Canal
Harbour
Life boat House
COURTOWN PIERS
Ruin of Stage
Old Mud Wall
New Pier



Cross Sections of 4

XXXIV.—Researches on the Parallax of 61 (A) Cygni, made at Dunsink. By Robert S. Ball, LL. D., F. R. S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.

[Read November 30, 1878.]

On the 22nd of August, 1868, my predecessor, Dr. Brünnow, commenced a series of observations with the South Equatorial, at Dunsink Observatory, with the view of making a new determination of the annual parallax of 61 Cygni. The method he adopted was to observe the difference of declination between the following star (B) of 61 Cygni and a star of the 9–10 magnitude, which in 1868 followed in 51·5 secs. at a distance of 104″ to the north. These observations were repeated occasionally by Dr. Brünnow, and the last was made on the 24th of May, 1873. There are altogether twenty determinations of the difference of declination between the two dates I have mentioned.

After I had had some practice in the use of the South Equatorial, I recommenced the series of observations on the differences of declination between 61 Cygni and the following star, which Dr. Brünnow employed. But there is an important difference between my series of observations, as here recorded, and those made by Dr. Brünnow, to which I have already referred. In the latter case the *following* component (B) of 61 Cygni was used, while in my observations it is the difference in declination between the *preceding* component (A) and the small star following which has been observed. It will naturally be asked why I did not use the same component as Dr. Brünnow had done, and thus render the two sets of observations capable of being incorporated together. I confess that in the first instance this was due to an inadvertence on my part. I was at first under the impression that Dr. Brünnow had used the preceding star (A) of 61 Cygni, and under this impression I commenced my work by measuring the difference of declination between (A) and the small star following. It was not until I had made a large number of observations that I became aware the component I was using was not the same as that which Dr. Brünnow employed; and when this discovery was made, the question arose as to the best course to be adopted. I felt reluctant to discard the work I had already done, and recommence anew with the other component, and therefore I resolved to complete the series of measurements which I had commenced, and thus, in the first instance, to seek for a determination of the annual parallax from my own observations alone. At the same time, I decided to commence as soon as possible another series of observations which would be strictly in continuation with Dr. Brünnow's work. At the present date these observations have made considerable progress, but their reduction or discussion has not yet been commenced. It will therefore be under-

stood that in the present Paper these observations are not referred to, and that the value of the parallax now presented has been solely founded on the observations of the difference of declination between (A) and the small star following.

In adopting this course, I was also influenced by some other considerations. In the researches of Struve on the annual parallax of 61 Cygni, he employed the star (B), as Dr. Brünnow had done. It however appeared to me that on this very account a determination of the parallax in which the preceding star was used would be, if successful, of very considerable interest. As this was the first work of the kind in which I had engaged, I was glad to have an opportunity of the practice which it afforded, before I commenced a series of measures which were to be amalgamated with those obtained by the mature skill of my predecessor.

I have to regret that, owing principally to the exceedingly bad weather which prevailed here during the winter of 1877–8, the number of observations is not so large as I would have wished. The observations yield thirty-six equations of condition for the determination of the four unknown quantities on which the apparent difference of declination depend. These equations contain the results of observations made on thirty-five different nights, which are only tolerably well distributed over the twelve months during which the observations extend. The method of observing which I have used is almost identical with that employed by Dr. Brünnow in his researches on the parallax of 61 Draconis (*Observations and Researches at Dunsink*, Parts I. and II.). A complete observation of the difference of declination is the mean of eight independent determinations.

The observations were reduced by employing the values of the micrometer screws and the thermometric coefficients determined by Dr. Brünnow (Part I., p. 8). The results were then cleared from refraction by the application of the correction

$$+ kD \operatorname{cosec}^2 (\delta + m),$$

where D is the apparent difference of declination, δ is the declination of 61 Cygni, and m is the function of the hour angle defined in Bessel's Table, *Astr. Unt. Bd.* 1, p. 190, and computed here for the latitude of Dunsink (53° 23′ 13″).

To clear the observed difference of declination from the effects of precession, aberration, and nutation, and reduce the result to the date 1878·0, the following correction is applied:—

$$+ 0''{\cdot}05266\ (1878 - t)$$
$$+ [6{\cdot}3089]\ i$$
$$- [6{\cdot}4137]\ h \cos (H + \alpha)$$
$$+ [7{\cdot}5735]\ g \sin (G + \alpha)$$
$$+ [7{\cdot}3643]\ h \sin (H + \alpha).$$

i, h, g, H, G, are the well-known constants in the Nautical Almanac; t is the year in which the observation was made; α is the right ascension of 61 Cygni.

In order to free the observations from the grosser part of the effects of the large proper motion of 61 Cygni, I have assumed that the small comparison star is at rest, and that the preceding star A has the annual proper motion assigned to it by Argelander, viz.:

$$+ 3''{\cdot}232.$$

When these various corrections have been applied, the following are the values of the differences of declination:—

1877.			1877.		
July	3,	66″·879	Dec.	13,	67″·701
	6,	66 ·899		14,	67 ·474
	19,	66 ·739		17,	67 ·482
	22,	66 ·927		19,	67 ·326
	24,	66 ·901		29,	67 ·350
Aug.	4,	66 ·798		30,	67 ·553
	12,	66 ·867	1878.		
	31,	66 ·959	Jan.	31,	67 ·659
Sept.	3,	66 ·695	Mar.	24,	67 ·273
	21,	66 ·942		24,	67 ·433
	27,	66 ·897		31,	67 ·252
Oct.	1,	66 ·888	April	1,	67 ·001
	8,	67 ·304		17,	67 ·224
	16,	67 ·013		24,	67 ·161
	23,	67 ·195		27,	66 ·852
	25,	67 ·021	May	18,	66 ·851
	29,	67 ·369		28,	66 ·688
Nov.	2,	67 ·300	June	1,	67 ·341
	13,	67 ·344			

Assuming that the true mean value of the difference of declination is $67''{\cdot}150 + x$, that the true relative proper motion of A and the comparison star is $3''{\cdot}232 + x'$, that π is the annual parallax, and that k is the difference in the coefficients of aberration for the two stars, then the observations yield thirty-six equations, which, being solved in the usual manner, give

$$x = + 0''{\cdot}0274 \pm 0''{\cdot}0210$$

$$x' = - 0\ {\cdot}0943 \pm 0\ {\cdot}1218$$

$$\pi = + 0\ {\cdot}4654 \pm 0\ {\cdot}0497$$

$$k = + 0\ {\cdot}0330 \pm 0\ {\cdot}0493$$

I subjoin the various determinations of the annual parallax of

61 Cygni, which have been hitherto given (*see* Auwer's *Abhandlungen der Akademie zu Berlin*, 1868).

Bessel, first fourteen months, . . .	0″·357
Bessel, last three months, and Schlüter, .	0 ·536
Johnson, first eleven months, . . .	0 ·526
Johnson, last seven months, . . .	0 ·192
Struve, ...	0 ·511
Auwers, ...	0 ·564

To these should be added the result obtained by Peters from zenith distance observations—

Peters, ...	0″·349

Auwers concludes, from his discussion of the whole subject, that the value of half a second is more likely to be correct than the smaller value which some of the observers have found. The new series of observations here described seem to support this view.

The complete details of these observations and their discussion are about to be published in Part III. of the *Dunsink Observations;* but I have thought that this brief account of the results might be of interest to the Academy.

XXXV.—NOTE ON THE APPLICATION OF LAGRANGE'S EQUATIONS OF MOTION TO PROBLEMS IN THE DYNAMICS OF A RIGID BODY. By ROBERT S. BALL, LL. D., F. R. S., Andrew Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.

[Read February 24, 1879].

THE problem to which I wish to direct attention occurs in the *Theory of Screws*, and is thus expressed in the language of that Theory.

A quiescent rigid body has freedom of the n^{th} order: being given the co-ordinates of an impulsive wrench, it is required to find the co-ordinates of the corresponding instantaneous screw.

The solution of this problem is given in the *Theory of Screws*, p. 60. The method there adopted is quite different from that now communicated, which is founded on Lagrange's *Equations of Motion in Generalized Co-ordinates*.

Without any loss of generality we may assume that the impulsive wrench is on a screw which belongs to the screw system, defining the freedom of the body; for, owing to the reactions of the constraints, one screw (but only one) can always be found in the screw system, a wrench on which would produce the same effect as a wrench on a screw otherwise placed.

Under these circumstances, let ζ_1, &c., ζ_n, represent the co-ordinates of the impulsive screw, and θ_1, &c., θ_n, be the co-ordinates of the corresponding instantaneous screw, reference being made as usual to the principal screws of inertia.

Lagrange's equations are typified by

$$\frac{d}{dt}\left(\frac{dT}{d\dot{\theta}_1}\right) - \frac{dT}{d\theta_1} = -P_1,$$

where T is the kinetic energy, and where $P_1\delta\theta_1$ denotes the work done in a twist $\delta\theta_1$ against the forces.

If ζ'' represent the intensity of the impulsive wrench, then

$$P_1 = 2p_1\zeta''\zeta_1$$

$$T = M(u_1^2\dot{\theta}_1^2 + \&c. + u_n^2\dot{\theta}_n^2),$$

where p_1, p_n, &c., are the pitches of the principal screws of inertia,

and u_1, &c., u_n, certain constants pertaining to those screws, and depending upon the mass of the body and its freedom.

We have, therefore,

$$\frac{d}{dt}(Mu_1^2\dot{\theta}_1) = -\zeta'' p_1\zeta_1,$$

whence, integrating during the small time t,

$$Mu_1^2\theta_1\dot{\theta} = -\zeta_1 p_1 \int_0^t \zeta'' dt\,;$$

so that θ_1, &c., θ_6, are proportional respectively to

$$\frac{p_1\zeta_1}{u_1^2},\ \&c.,\ \frac{p_n\zeta_n}{u_n^2}.$$

Q. E. D.

XXXVI.—Observations in Search of Stars with a Large Annual Parallax. By Robert S. Ball, LL.D., F.R.S., Royal Astronomer of Ireland.

[Read December 9, 1878.]

In continuing the researches made by my predecessor Dr. Brünnow, on the Parallax of Stars, I have adopted two different classes of observation. The first of these is the ordinary continuous series of observations of two or three specially chosen objects extending over an entire year. This is, no doubt, the only method by which a parallax amounting to a small portion of a second can be detected, much less accurately measured. It is, however, to be observed, that as a set of measures takes at least an hour to complete, it is almost impossible for the most assiduous observer to have more than three stars in hand at the same time. I have, therefore, adopted the course of having two stars in regular observation at the same time, and of devoting whatever other opportunities I may have to the system of observations which will be described in the present Paper. The full details of the observations here referred to will shortly appear in Part III. of the *Dunsink Observations*.

It is, of course, well known that up to the present no parallax has been detected which exceeds a single second of arc. In the great majority of cases the parallax is very much less, even if it be appreciable. But when we reflect that not one star out of every ten thousand has yet been regularly examined for parallax, it is obvious that it would be in the highest degree rash to conclude that there are no stars nearer to us than any of those of which we already know the distance.

In selecting objects appropriate for investigation of annual parallax, astronomers have generally chosen those stars which are exceptional, either on account of their brilliancy, or the largeness of their proper motions. The presence of these exceptional features in a star is doubtless a *prima facie* presumption that the star is comparatively near us. On the other hand, it cannot but be observed that the brightest star (*i.e.* Sirius) appears to have a parallax of only 0″·232,[1] while for the star Groombridge, 1830, which has the enormous proper motion of 7″·05 annually, Brünnow has found a parallax no greater than 0″·090. The presumptions of nearness founded on great brilliancy or great proper motion can hardly be said to be justified by the results of observation.

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[1] From Houreau's invaluable *Répertoire des Constantes de l'Astronomie* I extract the following:—"Jacq. Cassini, by the method of absolute altitudes in 1717, found a parallax of 6″ for Sirius. Piarri, by the same method, in 1805 reduced this to 4″. Henderson, in 1840, from the meridian altitudes at the Cape, found the value 0″·23. Gyldén, in 1864, from the altitudes found by Maclear, at the Cape, in 1836-7, deduced a parallax of 0″·193. Abbe, in 1868, from the altitudes at the Cape, in 1856–1863, deduced the parallax 0″·273. A mean of the three last determinations is the value given above."

The question then arises as to whether there are any additional presumptions which may guide the parallax seeker in choosing the stars to observe. I will mention two.

In Mr. G. J. Stoney's memoir on the "Physical Constitution of the Sun and Stars," *Proceedings of the Royal Society*, No. 105, 1868, p. 49, is the following passage :—

"The minute crimson stars which are met with here and there in the sky seem to be either very small stars or stars enormously distended by heat. It is very desirable that the proper motion and parallax of these bodies should be inquired into when practicable, on the chance that some of them may be found to owe their colour to being very small, and therefore very close to us."

There is also a certain presumption that some of the variable stars are really small, and that therefore, as we see them, they must be comparatively near us.

Before commencing the observations now about to be described, a working list was formed, containing Red Stars, variable stars, stars with large proper motion, and several other stars which were chosen on different grounds. The observations of these stars are directed with the special object of seeing whether any of them have a large parallax. My present purpose is to place on record the observations of forty-two different objects selected from this working list. In almost every case here described the observations have been sufficient to convince me that the parallax is *certainly less than one second of arc, and most probably does not exceed half a second.* It will, therefore, be understood that the results of the reconnoitring observations which are here set forth are merely negative so far as the immediate object in view is concerned; and as they do not suggest the existence of any parallax worth following up, I do not intend to observe the objects herein named any further. The time, therefore, seems to have arrived when these observations may be published.

We have now to describe the principle upon which the reconnoitring observations have been conducted. The effect of annual parallax upon a star is to make the apparent place of the star describe a minute ellipse, of which the mean place of the star occupies the centre. In the reconnoitring observations the star is observed twice; at the first observation the star is at one of the extremities of the major axis of the ellipse. The second observation is made after an interval of six months, during which time the star has moved to that part of the ellipse which is at the other extremity of the major axis. It thus appears that the two observations are so arranged that in each case parallax shall have the greatest effect it is capable of producing.

When a star undergoes the greatest displacement from parallax it must be at a distance of 90° from the sun. If, therefore, α, α', and δ, δ', be the right ascension and declension of the star and the sun, respectively, then, at the time of greatest parallactic displacement,

$$\tan \delta \tan \delta' = - \cos (\alpha' - \alpha).$$

By the aid of this formula the working list was arranged. For a given date the values of α', δ' are known, and the above formula gives a relation between α and δ. Taking lengths proportional to α, δ as abscissæ and ordinates, respectively, twenty curves were plotted on a plane corresponding to dates uniformly distributed over the year. These curves, of course, agree in passing through the point which corresponds to the pole of the ecliptic. By the aid of these curves, when the right ascension and declination of an object are known, it is easy to see at a glance when the object is 90° from the sun. The two critical dates were thus found for each of the objects in the working list, and the observations were always made as nearly as possible at these critical dates.

The instrument employed was the South Equatorial, with the Pistor and Martin's micrometer. The mode of observation was almost identically that adopted by Dr. Brünnow in his observations of α Lyræ and its companion (see *Dunsink Observations*, Part I.). The following is the method by which the observations have been reduced, and the different corrections applied:—

We shall denote the two stars by S, S', the two wires of the micrometer by I, II, and the two possible positions of the micrometer by A, B: then, the expression, AIS', for example, denotes the reading of the screw I. when placed upon the star S', the micrometer having the position A. A complete measure of the distance of the two stars is obtained by placing one wire on each star, reading off the screws, then interchanging the wires, and reading again. A complete series of measures consists of four such pairs, two being taken in the position A, and two in the position B. Each of the four complete measures are computed separately, the two first by the formula

$$\frac{r_1}{2}(AIS - AIS') + \frac{r}{2}(AIIS' - AIIS).$$

the two last by the formula

$$\frac{r_1}{2}(BIS' - BIS) + \frac{r_2}{2}(BIIS - BIIS'),$$

r_1, r_2 denote the values of a revolution of screws I., II., respectively. expressed in seconds of arc. These values have been computed from the expressions found by Dr. Brünnow—

$$r_2 = 1{\cdot}001337\, r_1,$$
$$r_1 = 8''{\cdot}9927 - 0''.0002922\,(\tau - 50°),$$

where t is the temperature Fahrenheit. In each observation the temperature is read off upon a thermometer, which, for convenience, is screwed to the finder of the telescope, the bulb of the thermometer being sixteen inches distant from the eye-piece of the telescope. For convenience in reducing the observations a table is used, which gives $\log r_1 - \log 2$ and $\log r_2 - \log 2$ for each degree.

The direction of the daily motion, or the "parallel," was determined as follows:—Wire I was set to the middle of the field, the

micrometer was turned, approximately, to the right position, and clamped; the driving clock was set in motion, and the star was brought by the slow motions to coincide with the intersection of I and the fixed wire. The clock was then stopped, and the micrometer was adjusted by the tangent screw so that the star ran along the fixed wire. In a second observation care was taken that the tangent screw was turned the opposite way when making the final adjustment. The observations of position were then made, and at the close of the series two more observations of the parallel were made, with the same precautions as before, but with the micrometer 180° from its position in the first set. The mean of the four observations was adopted as the "parallel." On referring to the observations, it will be seen that on many occasions the set of parallel observations was not so complete as is here described. Such care in determining the parallel as is necessary when the stars are three or four minutes apart would, of course, be thrown away if the stars were comparatively close together.

In observing the position, the micrometer was turned until the fixed wire was placed over the two stars, and the final adjustment was made with the tangent screw. This observation was then repeated, the head of the screw being turned the opposite way on the second occasion. The micrometer was then turned through 180°, and two more observations were made, with similar precautions. Thus, a complete determination of the position angle involves four readings of the parallel and four of the position.

The observations thus made have to be corrected for the effects of refraction, aberration, precession, and nutation. We shall consider them separately.

Let D be the distance of the two stars, and let p be the position angle; then, if z be the zenith distance, η the parallactic angle, and k the coefficient of refraction, the correction to be applied to the apparent distance for refraction is

$$kD(1 + \tan^2 z \cos^2 (p - \eta)),$$

where k is the coefficient of refraction taken from Bessel's Tables, *Ast. Unt.* Bd. I., p. 198. To facilitate the calculation of z and η, the table suggested by Bessel has been computed, which gives the values of m, and log cot n for each minute of hour angle in the latitude of Dunsink, 53° 23′ 13″. We can then readily compute z and η from the formulæ—

$$\tan \eta = \cot n \sec (\delta + m),$$

$$\tan z = \sec \eta \cot (\delta + m).$$

In using these expressions it is supposed that eastern hour angles are negative; cot n has the sign of the sine of the hour angle, and m has the sign of the cosine of the hour angle.

In applying the correction for refraction to the observation of the position angle, it is, of course, to be remembered that the reading of

the parallel is also affected by refraction: we have thus the expression

$$3438\ k \tan^2 z \cos p \sin (2\eta - p)$$

to denote the correction expressed in minutes of arc, which is to be applied to the observed position angle in order to clear it from the effects of refraction.

The distance of the two stars is also affected to a certain extent by aberration. The correction to be applied to the observed distance is

$$D \sin 1'' (i \sin \delta - h \cos (H + \alpha) \cos \delta),$$

where i, h, H, are given in the *Nautical Almanac* for the day in question. When this correction has been applied to the observed distance of the two stars, we obtain the distance between the mean places of the two stars for the preceding 1st January.

The position angle of the two stars is also affected by aberration, and the correction to be applied, expressed in minutes of arc, is

$$-\frac{h}{60} \sin (H + \alpha) \tan \delta.$$

On account of the motion of the pole, arising from precession and nutation, there is a corresponding change in the direction of the parallel, and therefore a change in the position angle; the correction

$$-\frac{g}{60} \sin (G + \alpha) \sec \delta$$

will make the position angle what it would have been when referred to the position of the pole on the preceding January 1. The quantities g, G, are those given in the *Nautical Almanac* for each day.

As the observations are all reduced to the epoch January 1st, 1875, a further correction,

$$-0{\cdot}3342\ (t - 1875) \sin \alpha \,.\, \sec \delta,$$

must be applied to the position angle observed in the year t.

Corrections must also be sometimes applied on account of the differences between the proper motions of the two stars. Let

$$(t - 1875)\ \Delta\alpha \text{ and } (t - 1875)\ \Delta\delta$$

be the corrections arising from the proper motions of the principal star relatively to the other star, which must be applied to the right ascension and declination of the principal star to bring the place to the date, January 1st, 1875. Then, the correction to be applied to the distance is

$$\cos p \Delta\delta\ (1875 - t) + \cos \delta \sin p \Delta\alpha\ (1875 - t),$$

while the correction to be applied to the minutes of the position angle is

$$3438 \sin p \frac{\Delta\delta}{D} (1878 - t) - 3438 \cos \delta \cos p \frac{\Delta\alpha}{D} (1875 - t).$$

By the application of these several corrections, the observed distance and position angle of the two stars is transformed into the true distance and position angle when the stars are situated in their mean positions on 1st January, 1875.

The following catalogue contains the results of these observations for forty-two different objects selected from the working list, of which the construction has been already explained. The first column of the catalogue contains the number of the object for convenience of reference. The second column gives the designation of the object. Frequent reference is here made to the list of Red Stars compiled by Schjellerup (Vierteljahrschrift der Astronomischen Gesellschaft IX. Jahrgang). This catalogue is referred to by the abbreviation "Schj." (Red). In other cases (as, for example, No. VI.) the reference (+ 27°, 1270) is, as usual, to the "Durchmusterung," vols. iii., iv., v., of the *Bonn Observations*. No. XXXI. is a Red Star from Mr. Birmingham's Catalogue (*Transactions* of the Royal Irish Academy, vol. xxvi., pp. 249–354).

The third column gives the date of the observation, which is always as near as possible to one of the two critical dates already referred to. In connexion with these critical dates, it is to be remembered that they have been chosen without reference to the comparison star, and therefore are not generally the precise dates at which parallax would make the maximum derangement of either the distance or the position angle. They are only the dates at which the star is situated at the apses of the parallactic ellipse. If the comparison star happened to be situated in the direction of the minor axis of the parallactic ellipse, there would be no parallactic change in the distance at the two dates, but there would be the greatest change possible in the position. On the other hand, if the comparison star were situated on the major axis of the parallactic ellipse, there would be the greatest change possible in the distance. It might, no doubt, have been better, in some respects, to have chosen the dates so that absolutely the maximum alterations of distance and position should have been secured, but this would have involved more time than I cared to devote to work which might probably lead only to a negative result. This method would, generally, have required five observations. The first of these would be devoted to the selection of a suitable comparison star, and a determination of its place; then, from these results the four dates of maximum and minimum derangement of distance and position, respectively, would have been determined, and the observations would have to be renewed at or near these dates. I have, therefore, adopted the simpler method, which only requires two observations, these being generally about the dates when the star is at its greatest distance on one side or the other of its mean place.

The fourth column gives the corrected distances, and the fifth column contains the corrected values of the position angles.

No.	Object.	Date.	Corrected Distance.	Corrected Position.
I.	Schj. (red), 3, . .	12 Aug., 1877,	183″·733	316° 5′ ·76
		31 Jan., 1878,	183 ·079	316 15 ·87
II.	Schj. (red), 3 *a*, .	1 Aug., 1876,	91 ·286	68 34 ·64
		12 Jan., 1877,	91 ·336	68 11 ·00
		19 Dec., 1877,	91 ·560	67 53 ·44
III.	Schj. (red), 28, .	17 Feb., 1877,	332 ·919	236 6 ·45
		31 Aug., 1877,	332 ·135	235 37 ·80
IV.	Schj. (red), 29, .	20 Feb., 1877,	229 ·778	85 16 ·90
		31 Aug., 1877,	229 ·801	85 10 ·26
V.	Schj. (red), 64, .	9 Oct., 1876,	263 ·831	191 49 ·17
		5 April, 1878,	263 ·677	191 32 ·33
VI.	+ 27°, 1270, . .	28 Mar., 1877,	169 ·368	218 50 ·85
		1 Oct., 1877,	169 ·163	218 44 ·05
VII.	+ 25°, 1594, . .	28 Mar., 1877,	105 ·799	87 11 ·30
		27 Sept., 1877,	105 ·985	87 8 ·93
		11 Oct., 1877,	105 ·873	86 59 ·18
VIII.	53 Geminor, . .	5 April, 1877,	209 ·359	315 46 ·93
		16 Oct., 1877,	208 ·886	315 52 ·76
IX.	Schj. (red), 94 *a*, .	5 April, 1877,	100 ·363	182 40 ·56
		16 Oct., 1877,	100 ·170	182 27 ·34
X.	+ 28°, 1532, . .	27 Mar., 1877,	242 ·772	293 20 ·83
		13 Nov., 1877,	243 ·248	293 27 ·28
XI.	+ 28°, 1532, . .	27 Mar., 1877,	185 ·079	345 4 ·02
		13 Nov., 1877,	185 ·056	345 24 ·61
XII.	Schj. (red), 115, .	25 Nov., 1876,	183 ·888	226 0 ·57
		27 Nov., 1876,	184 ·758	226 16 ·27
		17 April, 1878,	183 ·638	225 32 ·70
		21 April, 1878,	183 ·565	225 37 ·31
XIII.	Schj. (red), 120, .	7 May, 1877,	122 ·463	170 15 ·80
		17 May, 1877,	121 ·752	170 2 ·94
		10 Dec., 1877,	122 ·602	170 41 ·00
XIV.	R. Leonis = Schj. (red), 123,	27 Nov., 1876,	258 ·247	268 20 ·64
		8 Dec., 1876,	258 ·374	268 33 ·20
		12 Dec., 1876,	258 ·708	268 26 ·44
		17 May, 1877,	257 ·719	268 25 ·19
XV.	R. Leonis = Schj. (red), 123,	27 Nov., 1876,	275 ·722	224 32 ·44
		14 Dec., 1876,	276 ·120	224 41 ·80
		17 May, 1877,	274 ·241	224 37 ·59

No.	Object.	Date.	Corrected Distance.	Corrected Position.
XVI.	Schj. (red), 146, .	22 Dec., 1876,	276″·699	108° 43′ ·18
		5 May., 1878,	276 ·391	108 33 ·45
XVII.	Schj. (red), 155, .	14 Dec., 1876,	196 ·436	49 15 ·42
		8 June, 1877,	195 ·508	49 10 ·45
XVIII.	Schj. (red), 156, .	8 Jan., 1877,	393 ·856	344 15 ·94
		12 June, 1877,	392 ·083	344 3 ·56
XIX.	Schj. (red), 163, .	12 Jan., 1877,	271 ·843	240 6 ·09
		16 June, 1877,	271 ·888	232 52 ·94
XX.	Schj. (red), 163, .	12 Jan., 1877,	59 ·275	158 31 ·89
		16 June, 1877,	58 ·510	158 30 ·90
XXI.	+ 15°, 2891, . .	18 Feb., 1877,	131 ·406	45 16 ·06
		1 Aug., 1877,	130 ·854	45 4 ·13
		28 Aug., 1877,	131 ·079	45 15 ·85
XXII.	Schj. (red), 182, .	9 Jan., 1877,	391 ·615	341 1 ·31
		16 Feb., 1877,	392 ·353	340 52 ·42
		29 July, 1877,	390 ·977	341 3 ·54
XXIII.	Schj. (red), 185, .	4 Mar., 1877,	75 ·799	49 35 ·47
		17 Mar., 1877,	75 ·509	49 21 ·36
		2 Aug., 1877,	76 ·297	49 31 ·24
XXIV.	Schj. (red), 186, .	4 Mar., 1877,	132 ·579	9 32 ·86
		2 Aug., 1877,	132 ·807	9 2 ·11
XXV.	+ 46°, 2194, . .	28 Feb., 1877,	133 ·974	91 18 ·26
		30 Aug., 1877,	133 ·683	91 45 ·20
XXVI.	Schj. (red), 199 *a*,	16 Sept., 1876,	288 ·433	291 9 ·06
		4 April, 1878,	287 ·352	290 7 ·70
XXVII.	Schj. (red), 211 (*a*),	17 Mar., 1877,	165 ·101	143 49 ·73
		1 Oct., 1877,	164 ·866	143 3 ·07
XXVIII.	+ 23°, 3316, . .	27 April, 1878,	209 ·621	317 55 ·96
		27 Sept., 1877,	209 ·660	318 8 ·02
XXIX.	+ 24°, 3400, . .	21 Sept., 1877,	263 ·065	260 45 ·06
		24 April, 1878,	262 ·570	260 35 ·46
XXX.	+ 24°, 3405, . .	6 April, 1877,	128 ·481	221 51 ·15
		21 Sept., 1877,	127 ·989	222 6 ·31
XXXI.	+ 36°, 3168, . .	16 Oct., 1877,	134 ·311	355 14 ·81
		21 April, 1878,	134 ·778	354 31 ·55
XXXII.	Schj. (red), 221 (*a*),	14 Oct., 1876,	168 ·227	12 40 ·68
		17 May, 1877,	169 ·291	12 11 ·35

No.	Object.	Date.	Corrected Distance.	Corrected Position.
XXXIII.	Schj. (red), 221 (a),	14 Oct., 1876,	122″·059	121° 27′ ·33
		17 May, 1877,	121 ·394	121 40 ·57
XXXIV.	Schj. (red), 225, .	23 May, 1877,	48 ·677	82 32 ·26
		8 Oct., 1877,	47 ·832	82 59 ·95
		5 May, 1878,	48 ·386	—
XXXV.	+ 22°, 3660, . .	7 May, 1877,	255 ·704	254 44 ·96
		3 Sept., 1877,	256 ·231	254 40 ·47
XXXVI.	+ 35°, 3985, . .	25 May, 1877,	58 ·693	97 14 ·85
		6 Nov., 1877,	58 ·623	97 29 ·52
XXXVII.	+ 35°, 4001, . .	17 Nov., 1876,	60 ·430	330 6 ·20
		17 Nov., 1876,	61 ·497	330 5 ·40
		4 May, 1877,	62 ·019	329 47 ·31
		25 May, 1877,	61 ·418	330 1 ·93
XXXVIII.	+ 35°, 4001, . .	17 Nov., 1876,	86 ·466	182 10 ·68
		25 May, 1877,	86 ·546	181 35 ·05
XXXIX.	τ Cygni, . . .	15 Nov., 1876,	185 ·576	78 12 ·88
		25 May, 1877,	185 ·788	78 24 ·42
		12 June, 1877,	186 ·338	78 37 ·70
XL.	Schj. (red), 244, .	29 Nov., 1876,	124 ·265	8 10 ·20
		19 May, 1877,	123 ·652	7 34 ·88
XLI.	+ 41°, 4114, . .	12 Dec., 1876,	211 ·521	97 2 ·32
		27 May, 1877,	211 ·614	97 10 ·24
		15 June, 1877,	211 ·434	97 10 ·39
XLII.	+ 41°, 4117. . .	27 May, 1877,	211 ·095	67 40 ·43
		15 June, 1877,	210 ·923	67 45 ·15
		7 Nov., 1877,	211 ·286	67 51 ·31

It then became necessary to sift these observations with the view of seeing whether they afford any traces of parallax. A discrepancy between the distances or positions at the dates of the two observations must be attributed either, firstly, to the accidental errors of observation; or, secondly, to the proper motion of one or both of the two stars; or, thirdly, to the parallax of one or both of the two stars; or, fourthly, to the joint effect of various causes. It will be convenient, in considering the effect of parallax upon the position angle, to eliminate the effect of the distance by multiplying the actual correction to the position angle by the sine of the distance. If π be the parallax, and if the effect of parallax upon the distance be $\pi \cos \theta$, then the effect of parallax upon the position angle will be $\pi \sin \theta$. It follows that, when the object is observed at the apses of its paral-

lactic ellipse, the discrepancy between the two distances will be $2\pi \cos \theta$, and the discrepancy between the two position angles will be $2\pi \sin \theta$. These quantities cannot be both less than $\pi\sqrt{2}$. If, therefore, we retain for discussion every case in which the discrepancy in the two distances, or the two position angles, amounts to a single second of arc, every case in which the parallax could amount to $0''{\cdot}70$ will be certainly included. On examining the list of observations, it will be seen that in twenty-seven cases there is not a discrepancy, either in the angle of position or in the distance, which amounts to a single second of arc. In these cases there is, therefore, no suggestion that the parallax reaches anything like the limit named: if any appreciable parallax exists, it is masked in the errors of observation, which are, of course, under little control when the number of observations is so few.

There are, however, fifteen cases in which the discrepancy does amount to a second of arc. Thus, so far as the distance is concerned, in

XV.	the discrepancy is	$1''{\cdot}7$
XVIII.	,,	$1\ {\cdot}8$
XXII.	,,	$1\ {\cdot}0$
XXVI.	,,	$1\ {\cdot}1$
XXXII.	,,	$1\ {\cdot}1$

The following are the cases in which the discrepancy in the two position angles is at least equivalent to a second of arc:—

III., V., XI., XII., XIII., XVIII., XXIV., XXV., XXVI., XXVII., XXXI., XL.

In the case of XVIII. and XXVI., we have a discrepancy amounting to over a second both in the distance and the position angle.

It may be remarked, that of these fifteen cases a large proportion will be found where the observations have been more or less incomplete, and where, consequently, the errors of observation may reasonably be expected to be greater than in the cases where the observations are complete. We shall, however, inquire as to how far the discrepancies are capable of being subdued or removed by the supposition of annual parallax. For this purpose it will be necessary to examine the effect of annual parallax on each of the objects, separately, by the well-known formulæ. In order to reduce the observed distance between a star which has parallax π, and an adjacent star which has no parallax, to the distance, as seen from the sun, a correction must be applied equal to

$$-m\pi R \cos (\odot - M),$$

where R is the distance from the sun to the earth, and where $\odot$ is the sun's longitude, m, M being constants depending upon the object.

The corresponding correction to be applied to the position angle of the star which has no parallax, measured from the star which has parallax, is

$$-m'\pi R \operatorname{cosec} D \cos(\odot - M'),$$

where D is the distance of the two stars. The four quantities, m, m', M, M', have been computed from the well-known formulæ.

It is also sometimes useful as a check to calculate the effect of parallax on the distance and position by the other method, which is, indeed, much shorter than the general method just referred to, when only one or two observations have to be reduced.

Let α', δ', be the right ascension and declination of the sun at the time of the observation, then the following formulæ are computed:—

$$\rho \cos \sigma = \sin \delta', \qquad \lambda \cos \mu = \cos \delta' \sin (\alpha' - \alpha),$$

$$\rho \sin \sigma = \cos (\alpha' - \alpha), \qquad \lambda \sin \mu = \rho \cos (\sigma + \delta).$$

The correction to the distance is

$$+ \pi R \lambda \sin (p + \mu).$$

The correction to the position is

$$+ \pi R \lambda \operatorname{cosec} D \sin (p + \mu).$$

The result of the calculations is given in the following Table :—

Reference Number.	Object.	Date.	Apparent Distance Corrected for Annual Parallax π.	Apparent Position Corrected for Annual Parallax π.
III.	Schj. (red), 28, . .	1877. Feb. 17,	$332''.919 + 0''.921\,\pi$	$236^\circ\ 6'.45 + 3'.61\,\pi$
		,, Aug. 31,	$332\ .135 - 0\ .914\,\pi$	$235\ 37\ .80 - 3\ .73\,\pi$
V.	Schj. (red), 64, . .	1876. Oct. 9,	$263\ .831 - 0\ .227\,\pi$	$191\ 49\ .17 - 11\ .60\,\pi$
		1878. April 5,	$263\ .677 + 0\ .231\,\pi$	$191\ 32\ .33 + 11\ .82\,\pi$
XI.	+ 28°, 1532, . . .	1877. Mar. 27,	$185\ .079 + 0\ .451\,\pi$	$345\ 4\ .02 - 15\ .5\,\pi$
		,, Nov. 13,	$185\ .256 - 0\ .341\,\pi$	$345\ 24\ .61 + 15\ .3\,\pi$
XII.	Schj. (red), 115, .	1876. Nov. 25,	$183\ .888 - 0\ .455\,\pi$	$226\ 0\ .57 - 14\ .5\,\pi$
		,, ,, 27,	$184\ .758 - 0\ .448\,\pi$	$226\ 16\ .27 - 14\ .3\,\pi$
		1878. April 17,	$183\ .638 + 0\ .497\,\pi$	$225\ 32\ .70 + 15\ .8\,\pi$
		,, ,, 21,	$183\ .565 + 0\ .504\,\pi$	$225\ 37\ .31 + 16\ .0\,\pi$
XIII.	Schj. red), 120, .	1877. May 7,	$122\ .463 - 0\ .420\,\pi$	$170\ 15\ .80 + 25\ .6\,\pi$
		,, ,, 17,	$121\ .752 - 0\ .368\,\pi$	$170\ 2\ .94 + 24\ .0\,\pi$
		,, Dec. 10,	$122\ .602 + 0\ .206\,\pi$	$170\ 41\ .00 - 21\ .0\,\pi$
XV.	R Leonis, . . .	1876. Nov. 27,	$275\ .722 - 0\ .406\,\pi$	$224\ 32\ .44 - 10\ .9\,\pi$
		,, Dec. 14,	$276\ .120 - 0\ .356\,\pi$	$224\ 41\ .80 - 9\ .75\,\pi$
		1877. May 17,	$274\ .241 + 0\ .434\,\pi$	$224\ 37\ .59 + 11\ .4\,\pi$
XVIII.	Schj. (red), 156, .	1877. Jan. 8,	$393\ .856 - 0\ .552\,\pi$	$344\ 15\ .94 + 6\ .83\,\pi$
		,, June 12,	$392\ .083 + 0\ .710\,\pi$	$344\ 3\ .56 - 6\ .09\,\pi$
XXII.	Schj. (red), 182, .	1877. Jan. 9,	$391\ .615 - 0\ .829\,\pi$	$341\ 1\ .31 + 4\ .40\,\pi$
		,, Feb. 6,	$392\ .353 - 0\ .559\,\pi$	$340\ 52\ .42 + 7\ .08\,\pi$
		,, July 22,	$390\ .977 + 0\ .710\,\pi$	$341\ 3\ .54 - 6\ .36\,\pi$
XXIV.	Schj. (red), 186, .	1877. March 4,	$132\ .579 + 0\ .519\,\pi$	$9\ 32\ .86 + 24\ .97\,\pi$
		,, Aug. 2,	$132\ .807 + 0\ .162\,\pi$	$9\ 2\ .11 - 24\ .94\,\pi$
XXV.	+ 46°, 2194, . . .	1877. Feb. 28,	$133\ .974 + 0\ .982\,\pi$	$91\ 18\ .26 + 0\ .64\,\pi$
		,, Aug. 30,	$133\ .683 - 0\ .999\,\pi$	$91\ 45\ .20 - 1\ .85\,\pi$
XXVI.	Schj. (red), 199 (*a*),	1876. Sept. 16,	$288\ .433 + 0\ .926\,\pi$	$291\ 9\ .06 - 4\ .47\,\pi$
		1878. April 4,	$287\ .352 - 0\ .732\,\pi$	$290\ 7\ .70 + 7\ .32\,\pi$
XXVII.	Schj. (red), 211 (*a*),	1877. Mar. 17,	$165\ .101 + 0\ .644\,\pi$	$143\ 49\ .73 - 15\ .67\,\pi$
		,, Oct. 1,	$164\ .866 - 0\ .531\,\pi$	$143\ 3\ .07 + 17\ .65\,\pi$
XXXI.	+ 36°, 3168, . . .	1877. Oct. 16,	$134\ .311 - 0\ .187\,\pi$	$355\ 14\ .81 - 25\ .0\,\pi$
		1878. April 21,	$134\ .778 + 0\ .306\,\pi$	$354\ 31\ .55 + 24\ .2\,\pi$
XXXII.	Schj. (red), 221 (*a*),	1876. Oct. 14,	$168\ .227 - 0\ .393\,\pi$	$12\ 40\ .68 - 18\ .7\,\pi$
		1877. May 17,	$169\ .291 + 0\ .817\,\pi$	$12\ 11\ .35 + 12\ .6\,\pi$
XL.	Schj. (red), 244, .	1876. Nov. 29,	$124\ .265 - 0\ .565\,\pi$	$8\ 10\ .20 - 21\ .4\,\pi$
		1877. May 10,	$123\ .652 + 0\ .524\,\pi$	$7\ 34\ .88 + 23\ .9\,\pi$

In the great majority of cases these results pronounce emphatically against the supposition of a parallax large enough to be detected amid the errors of observation which are inseparable from the method which has been adopted. In no case do they afford reliable indications of a parallax large enough to be detected by the method of reconnoitring.

XXXVII.—SPECULATIONS ON THE SOURCE OF METEORITES. By ROBERT S. BALL, LL.D., F.R.S., Royal Astronomer of Ireland.

[Read January 13, 1879.]

I HAVE recently read M. G. Tschermak's most interesting memoir "Die Bildung der Meteoriten und der Vulcanismus."[1] I am not competent to offer any opinion on the mineralogical questions involved in his discussion, but the numerous arguments he has advanced appear to me to justify his conclusion, that "the meteorites have had a volcanic source on some celestial body." These arguments are briefly as follows:—

Meteorites are always angular fragments, even before they come into our atmosphere.

Most meteoric irons have a crystalline structure, which, according to Haidinger, requires a very long period of formation at a nearly constant temperature. This condition could only have been fulfilled in a large mass.

Many meteoric stones show flutings resembling those seen on terrestrial rocks, and which are due to the rubbings of adjacent masses.

Other meteorites have a structure produced by the union of several fragments, so as to be analogous to breccia.

Many meteorites are composed of very small particles analogous to volcanic tufas.

After glancing at the old theory of the volcanoes in the moon, and rejecting as untenable the hypothesis that meteorites have any connexion with the ordinary shooting star showers, Tschermak concludes, "We may suppose that many celestial bodies, of considerable dimensions, are still small enough to admit of the possibility that projectiles driven from them in volcanoes shall not return by gravity. These would really be the sources of meteorites." Similar views having been put forward by Mr. J. Laurence Smith and other authorities, it seems not unreasonable to discuss the following problem:—

If meteorites have been projected from volcanoes, on what body or bodies in the Universe must these volcanoes have been located?

Let us first take up a few of the principal celestial bodies *seriatim*, and consider their claims to the parentage of the meteorites. We begin with the sun. It has been shown that there exists upon the sun tremendous explosive power. It is not at all unlikely that the power would be sufficiently great under certain circumstances actually to drive a body from the sun never to return. We might, therefore, find upon the surface of the sun adequate explosive power for the volcano, but the projectiles are here the difficulty. There are a

[1] Sitzungsberichte der Mathematisch-Naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften, Wien, 1875. Band lxxi., Abtheilung 2, pp. 661–674.

number of circumstances (notably the breccia-like appearance of some meteorites) which show conclusively that the meteorites have been torn from rocks which were already nearly, if not quite, solid; and as it seems in the highest degree improbable that rocks of this nature should exist in the sun, we may conclude that the sun has not been the source of the meteorites.

Can the meteorites have come from the moon? Owing to the small mass of the moon, the explosive power requisite to carry a body away from the moon may no doubt be comparatively small; but can a body which has been projected from a volcano in the moon tumble upon the earth? *To simplify questions of this kind we shall suppose various disturbing influences absent.* We shall suppose that the projectile is discharged from the moon with sufficient velocity to carry it completely therefrom. We shall then omit all account of the disturbing influence both of the sun and the moon on the projectile, and we shall suppose that the projectile is really revolving round the earth as a satellite. This projectile will fall upon the earth if its distance from the earth's surface when in perigree be less than the radius of the earth (augmented perhaps by the thickness of the earth's atmosphere). It should, however, be observed, that *if the projectile once escaped the earth, it would never fall thereon;* hence the question as to whether the moon can be the source of the meteorites now falling appears to be connected with the question as to whether the lunar volcanoes are now active. But it is generally believed that the lunar volcanoes are not now active to any appreciable extent (even if the suspected indications of recent change were thoroughly established). It follows, that even if the moon has been a source of meteorites in ancient times, we no longer receive a supply from that quarter. There is, of course, just a possibility that projectiles from the moon in past ages, which have hitherto escaped collision with the earth, may, under the influence of the *disturbing causes previously excepted,* occasionally fall to the earth as a meteorite.

Passing from the sun and the moon, let us now bring under review some of the other celestial bodies, and see how far they will fulfil the conditions of the question, Is it possible that the meteorites can have been projected from the surface of a planet? In order to get over the difficulties of the great initial velocity which would be necessary to overcome the gravitation of a large planet, it seems natural to inquire if a volcano placed upon one of the small planets could accomplish the task.

It is clearly impossible that a projectile from any source should ever fall on the earth, unless the orbit of the projectile cuts the plane of the ecliptic in the narrow ring, something over 8000 miles wide, which the earth and its atmosphere trace out on the ecliptic; but if a meteorite with an elliptic orbit round the sun intersect this ring, then in the lapse of time it may happen that the earth and the meteorite will meet at the point where their orbits intersect; the meteorite will then fall upon the earth, and its long travels will be at an end.

We shall therefore consider the circumstances under which it would be possible for a volcano on one of the minor planets (for example, Ceres) to discharge a projectile so that the projectile shall intersect the ecliptic in the ring we have just referred to. As the mass of the planet is small, the initial velocity which would be required to carry a projectile away from the planet presents no difficulty, perhaps an ordinary cannon would be sufficient, *so far as the mere gravitation to the planet is concerned.* But when we consider that the projectile must be driven through the ring we have been considering, a vastly more powerful instrument would be required.

Ceres is moving in an orbit (supposed circular and in the ecliptic) with a velocity of about eleven miles per second. A projectile discharged from Ceres will have an actual velocity which is compounded of the velocity of Ceres, with the velocity which is imparted by the volcano. But simple dynamical considerations show that if the projectile have an initial velocity *perpendicular to the radius vector*, differing much from eight miles per second, it can never intersect the ring, no matter in what direction it be discharged.[2] The volcano on Ceres must therefore be adequate to the abatement of the velocity perpendicular to the radius vector from eleven miles per second to eight miles per second, *i.e.*, *the volcano must be at the very least adequate to producing an initial velocity of three miles per second.* As this is quite independent of the additional volcanic power requisite to carry the projectile away from the attraction of Ceres, it is obvious that after all there may be but little difference between the volcano which would be required on Ceres, and that (of six-mile power) which would project a body away from the surface of the earth for ever.

Admitting, however, that a volcano of sufficient power were placed upon Ceres, would it be likely that a projectile driven therefrom would ever cross the earth's track? This is a question in the theory of probabilities, and it is not easy to state the problem very definitely. If the *total* velocity with which the projectile leaves the orbit of Ceres be less than eight miles per second, then the projectile will fall short of the earth's track; on the other hand, if the *total* initial velocity exceeds sixteen miles per second, the orbit in which the projectile moves will be hyperbolic, and though it may cross the earth's track once, it will never do so again. Taking a mean between these extreme velocities we may investigate the following problem:—Suppose that a projectile is discharged from a point in the orbit of Ceres in a *random* direction with the *total* initial velocity of twelve miles per second, determine the probability that the orbit of the projectile shall cross the earth's track. When this problem is solved in accordance with the calculus of probabilities, it is found that the chances against the occurrence are about 50,000 to 1, *i.e.*, out of every 50,000 projectiles discharged at random from a point in the orbit of Ceres, only a single one can be expected to cross the earth's track.

[2] Disregarding an obvious exception.

It is thus evident that there are two objections to Ceres (and the same may be said of the other minor planets) as a possible source of the meteorites. Firstly, that notwithstanding the small mass of Ceres, a very powerful volcano would be required; and secondly, that we are obliged to assume that for each meteorite which could ever fall upon the earth, at least 50,000 must have been ejected.

It thus appears that if the meteorites have been originally driven from any planet of the solar system, large or small, the volcano must, from one cause or another, be a very powerful one.

There is, however, one planet of the solar system which has a special claim to consideration. On that planet it is true that a volcano would be required which was capable of giving an initial velocity of at least six miles per second; but *every* projectile launched from that volcano into space would, after accomplishing an elliptic orbit round the sun, dash through the track of the earth, and again pass through the same point at every subsequent revolution. It is not here a case of one solitary projectile out of 50,000 crossing the earth's track, but every one of the 50,000 possesses the same property. The planet of which we are speaking is, of course, the earth itself. If in ancient times there were colossal volcanoes on the surface of the earth which had sufficient explosive energy to drive missiles upwards with a velocity sufficient to carry them away from the earth's surface, after making allowance for the resistance of the air, these missiles would then continue to move in *orbits round the sun*, crossing at each revolution the point of the earth's track from which they were originally discharged. If this were the case, then doubtless there are now myriads of these projectiles moving through the solar system, the only common feature of their orbits being that they all intersect the earth's track. It will, of course, now and then happen that the earth and the projectile meet at the point of crossing, and then we have the phenomenon of the descent of a meteorite. The theory, that the meteorites have originated in the earth, was, so far as I know, first put forward by Dr. Phipson. Mr. J. Lawrence Smith, in a letter I received from him some months ago, inclines to the same view as at all events one of the probable sources.

It is well to note here the great difference between the lunar theory of meteorites and the terrestrial theory. For the lunar theory to be true it would probably be necessary that the lunar volcanoes should be *still* active. In the terrestrial theory it is only necessary to suppose that the volcanoes on the earth *once* possessed sufficient explosive energy. No one supposes that the volcanoes on the earth at present eject the fragments which will constitute future meteorites, but it seems probable that the earth may be now slowly gathering back in these quiet times the fragments she ejected *in an early stage of her history*.

Assuming, therefore, that the meteorites have had a *quasi*-volcanic origin on some considerable celestial body, I am led to agree with those who believe that most probably that body is the earth.

XXXVIII.—An Easy Mode of obtaining the complete Differential Equations of Motion of an Ocean surrounding a Solid Nucleus, and subject to any Disturbing Forces (the Nucleus itself revolving on a Fixed Axis); without Calculation or Transformation of Co-ordinates; from simple Geometrical and Mechanical Principles. By the Rev. Samuel Haughton, M.D., Dubl.; D.C.L., Oxon.

[Read April 14, 1879.]

The complete differential equations of the motion of the sea or atmosphere, referred to polar co-ordinates, are regarded, justly, as one of the most brilliant results that we owe to the genius of Laplace; and yet they are found to be a "stumbling-block" in the way of young mathematicians, from the hideously repulsive form in which they are deduced, by transformation, from fixed rectilinear co-ordinates, by Laplace himself, and by his followers.

Any attempt, therefore, to write down these equations at sight, from elementary geometrical and mechanical principles, will be regarded as useful.

According to the self-evident principle of D'Alembert, all problems of Dynamics are reducible to problems of Statics, by introducing velocities and accelerating forces, equal and opposite to the existing velocities and accelerating forces.

Now, the most general equations of equilibrium, of any system, are the following, six in number—

$$\begin{aligned} X &= 0, \quad Y = 0, \quad Z = 0, \\ L &= 0, \quad M = 0, \quad N = 0, \end{aligned} \tag{1}$$

where X, Y, Z, are the sums of the external forces resolved along three rectangular axes; and L, M, N, are the sums of the Couples (or Twists) of those forces round the axes of X, Y, Z, respectively.

The corresponding dynamical equations are—

$$\begin{aligned} X - \frac{d^2x}{dt^2} &= 0, \\ Y - \frac{d^2y}{dt^2} &= 0, \\ Z - \frac{d^2z}{dt^2} &= 0, \\ L - \frac{d}{dt}\left(z\frac{dy}{dt} - y\frac{dz}{dt}\right) &= 0, \\ M - \frac{d}{dt}\left(x\frac{dz}{dt} - z\frac{dx}{dt}\right) &= 0, \\ N - \frac{d}{dt}\left(y\frac{dx}{dt} - x\frac{dy}{dt}\right) &= 0. \end{aligned} \tag{2}$$

These equations become, in the case of an incompressible fluid—

$$\frac{dp}{dx} = X - \frac{d^2x}{dt^2},$$

$$\frac{dp}{dy} = Y - \frac{d^2y}{dt^2}, \qquad (3)$$

$$\frac{dp}{dz} = Z - \frac{d^2z}{dt^2},$$

where p is the common pressure of the fluid (equal in all directions) at any point (x, y, z).

It will be noted, that the last three equations of (2), depending on couples, disappear; because, in consequence of the mobility of the particles of the fluid, *inter se*, internal couples or twists become impossible.

The Laplacian equations of motion, in polar co-ordinates, are usually deduced from (3), by transformation of the co-ordinates, from x, y, z, referred to fixed axes, where the axis of x is the axis of rotation; that of y an axis perpendicular to x, and fixed in space; and that of z, an axis perpendicular to those of x, y; to r, θ', ϕ', where r is the radius vector, θ' is the north polar distance, and ϕ' is the angular distance from the plane of x, y, of the meridian of any moving particle.

Instead of referring the forces to fixed co-ordinates, I refer them to the following moveable rectangular co-ordinates :—

Axis of x'.

Let R denote the sum of the forces at any point, acting along the radius vector (*negative* towards the centre, and *positive* from it.)

Axis of y'.

Let S denote the sum of the forces at any point acting in the meridional moving plane, and perpendicular to r (*positive* towards the equator, and *negative* towards the pole.)

Axis of z'.

Let T denote the sum of the forces at any point acting perpendicularly to the two former directions, or in the direction of the tangent to the small circle of latitude (*negative* against the rotation, and *positive* with it.)

Let r, θ', ϕ', denote the polar co-ordinates in their most general form. The alteration in pressure produced by a change in r is similar to that produced by a change in x, y, z, of the first three of equations (2) (because they are all linear magnitudes), and denotes a *force* acting to or from the centre; but the alteration in pressure produced by a change in angular direction by a change in θ' or ϕ' is no longer

a *force*, but a *couple*, tending to turn the fluid round the centre. Thus,

$\frac{dp}{dr}$ is a *force* acting in the direction of the radius vector;

$\frac{dp}{d\theta'}$ is a *couple*, acting always in the moving meridional plane, and whose axis moves perpendicular to that plane;

$\frac{dp}{d\phi'}$ is a *couple*, acting always round the axis of rotation, and parallel to the equatorial plane.

It is evident that if D'Alembert's equations (2) are satisfied—

1°. For *forces* acting along the radius vector;
2°. For *couples* acting in the meridional plane in every possible position of that plane;
3°. For couples acting always round the axis of rotation;

complete Dynamical Equilibrium will be secured.

We may discount all the mechanical consequences of the rotation by introducing the centrifugal force, leaving only the geometrical consequences of the rotation, in the problem.

The geometrical effect of the rotation is expressed by writing

$$\phi' = nt + \phi',$$

where n is the angular velocity of the earth's rotation.

The components of the velocity of any particle along R, S, T, are—

$$\frac{dr}{dt}, \quad r\frac{d\theta'}{dt}, \quad r\sin\theta'\left(n + \frac{d\phi'}{dt}\right).$$

The centrifugal force affects the directions R, S, only, and does not enter into T.

The centrifugal force in the direction of R is, obviously,

$$\frac{r^2 d\theta'^2}{dt^2} + r^2 \sin^2\theta'\left(n + \frac{d\phi'}{dt}\right)^2 \Big/ r$$

From this, and from the first three equations (2) we find, at sight—

$$\frac{dp}{dr} = R - \frac{d^2r}{dt^2} + \frac{r d\theta'^2}{dt^2} + r\sin^2\theta'\left(n + \frac{d\phi'}{dt}\right)^2. \qquad (A)$$

*

The centrifugal force in the direction of S is, obviously,

$$r \sin \theta' \cos \theta' \left(n + \frac{d\phi'}{dt} \right)^2.$$

The sixth of equations (2) therefore becomes, remembering that

$$y' \frac{dx'}{dt} - x' \frac{dy'}{dt} = r^2 \frac{d\theta'}{dt},$$

and equating couples in the meridional plane—

$$\frac{dp}{d\theta'} = Sr - \frac{d}{dt} \left(r^2 \frac{d\theta'}{dt} \right) + r^2 \sin \theta' \cos \theta' \left(n + \frac{d\phi'}{dt} \right)^2. \qquad \text{(B)}$$

If we now equate the couples in the equatorial plane, we find, since

$$z \frac{dy}{dt} - y \frac{dz}{dt} = r^2 \sin^2 \theta' \left(n + \frac{d\phi'}{dt} \right),$$

$$\frac{dp}{d\phi'} = Tr \sin \theta' - \frac{d}{dt} \left(r^2 \sin^2 \theta' \left(n + \frac{d\phi'}{dt} \right) \right). \qquad \text{(C)}$$

The three equations just found from elementary principles are *exact equivalents* of the Laplacian differential equations, which are thus expressed by Airy[1] :—

$$\frac{dp}{dr} = X \frac{x}{r} + Y \frac{y}{r} + Z \frac{z}{r} - \frac{1}{2r} \frac{d^2(r^2)}{dt^2} + \frac{1}{r} \left(\frac{dr}{dt} \right)^2 + r \left(\frac{d\theta'}{dt} \right)^2 + r \sin^2 \theta' \left(n + \frac{d\phi'}{dt} \right)^2, \qquad \text{(A')}$$

$$\frac{dp}{d\theta'} = - X \sqrt{y^2 + z^2} + \frac{Yxy + Zxz}{\sqrt{y^2 + z^2}} - \frac{d}{dt} \left(r^2 \frac{d\theta'}{dt} \right) + r^2 \sin \theta' \cos \theta' \left(n + \frac{d\phi'}{dt} \right)^2, \qquad \text{(B')}$$

$$\frac{dp}{d\phi'} = Zy - Yz - 2r \frac{dr}{dt} \sin^2 \theta' \left(n + \frac{d\phi'}{dt} \right) - 2r^2 \sin \theta' \cos \theta' \frac{d\theta'}{dt} \left(n + \frac{d\phi'}{dt} \right) - r^2 \sin^2 \theta' \frac{d^2\phi'}{dt^2}. \qquad \text{(C')}$$

[1] "Tides and Waves," p. 264.

In addition to the foregoing differential equations of motion, the geometrical equation called the "Equation of Continuity" has to be found.

I here give it by means of an investigation more general and more simple than that used by Laplace and Airy.

Let

u = the *linear* velocity in the direction of the radius vector;

v = the *angular* velocity in latitude in the plane of the moving meridian;

w = the *angular* velocity in longitude.

If we imagine a prism erected on a *trapezoidal* base whose four corners are

(1). θ', ϕ'; (2). $\theta' + d\theta', \phi'$;

(3). $\theta', \phi' + d\phi'$; (4). $\theta' + d\theta', \phi' + d\phi'$;

the sides (1, 2) and (3, 4) are equal, and each $rd\theta'$; but the sides (1, 3) and (2, 4) are not equal; the first being $r \sin \theta' d\phi'$, and the second being $r \sin (\theta' + d\theta') d\phi'$, or

$$r (\sin \theta' + \cos \theta' d\theta') d\phi'.$$

If, now, z denote the variable depth of the sea, the quantity of water passing in the time dt, through the wall of the prism (1, 2), will be

$$z \times rd\theta' \times r \sin \theta' w dt.$$

The quantity of water passing in the same time through the wall (3, 4) will be

$$\left(z + \frac{dz}{d\phi'} d\phi'\right) \times rd\theta' \times r \sin \theta' \left(w + \frac{dw}{d\phi'} d\phi'\right) dt.$$

The difference of these quantities is

$$r^2 \sin \theta' d\theta' dt \left(w \frac{dz}{d\phi'} + z \frac{dw}{d\phi'}\right) d\phi',$$

or,

$$r^2 \sin \theta' d\theta' d\phi' dt \frac{d(wz)}{d\phi'}. \qquad (a)$$

The quantity of water flowing in the time dt through the wall (1, 3) is

$$z \times r \sin \theta' d\phi' \times rv dt,$$

and in the same time there passes through the wall (2, 4) the quantity

$$\left(z + \frac{dz}{d\theta'}\, d\theta'\right) \times r^2 d\phi'\, dt \times \left(v \sin\theta' + \frac{d\,(v \sin\theta')}{d\theta'} d\theta'\right).$$

The difference of these quantities is

$$r^2 d\theta'\, d\phi'\, dt \left(z \sin\theta' \frac{dv}{d\theta'} + zv \cos\theta' + v \sin\theta' \frac{dz}{d\theta'}\right),$$

which is equivalent to

$$r^2 \sin\theta'\, d\theta'\, d\phi'\, dt \left(\frac{d(vz)}{d\theta'} + vz \cot\theta'\right). \qquad (b)$$

The sum of (a) and (b) is the excess of inflow or outflow, in the time dt, through the four walls of the trapezoidal prism. Now, as the bottom of the sea is fixed and allows no inflow or outflow, the sum of (a) and (b) must be equal to the area of the trapezoid, multiplied by the rise or fall of the surface (taken with its proper sign).

This volume will be

$$r^2 \sin\theta' d\theta' d\phi'\, dt \times u. \qquad (c)$$

Hence, adding (a), (b), and (c) together (with a proper sign for u), we obtain

$$u + \frac{d\,(wz)}{d\phi'} + \frac{d\,(vz)}{d\theta'} + vz \cot\theta' = 0. \qquad (D)$$

This is Laplace's famous Equation of Continuity, and is identical with that given by him (*Méc. Cel.*, vol. i. p. 104), when the notation is changed into his notation.

Equation (D) may be thus written :—

$$u + z\left(\frac{dw}{d\phi'} + \frac{dv}{d\theta'} + v \cot\theta'\right) + \left(w \frac{dz}{d\phi'} + v \frac{dz}{d\theta'}\right) = 0.$$

The second part of this equation vanishes when the sea has a constant depth ; in which case the Equation of Continuity reduces to the form

$$u + \delta\left(\frac{dw}{d\phi'} + \frac{dv}{d\theta'} + v \cot\theta'\right) = 0, \qquad (D)$$

where δ is the constant depth of the sea.

Every conceivable problem, in tidal motion and oceanic current circulation, is theoretically solved by equations A, B, C, and D; and the only further difficulties are practical, arising from the imperfection of our mathematical knowledge.

XXXIX.—On a Cylindrical Mass of Basalt existing at Contham Head, Moon Bay, Coast of Antrim.

By Joseph P. O'Reilly, C. E., Central School of Paris; Professor of Mining and Mineralogy, Royal College of Science for Ireland. Plates 8 and 9.

[Read May 12, 1879.]

When engaged in studying the forms of columnar basalt at the Giant's Causeway, I had occasion to observe and to take sketches of a very remarkable cylindrical form of that rock, which occurs at the N. W. point of Moon Bay, marked Contham Head on the Ordnance Map, and situated at about two miles distance east of the Giant's Causeway.

When first observed by me in 1875, I was quite unable to explain its origin and connexion with the containing rock; but having subsequently revisited the locality, for its further examination, and the making of a few sketches, I was enabled to arrive at certain conclusions as to the nature and origin of this remarkable form, which I beg leave to submit to the Academy.

Contham Head is a small promontory or spit of basaltic rock, extending out into the sea about 250 feet, its breadth at the water level being about 200 feet. There is a central rib rising above the underlying basalt bed, about twenty to thirty feet at most, having a length of about 150 feet, and a breadth of about fifty feet.

This low, narrow, and relatively short promontory is only accessible from the cliffs by a narrow and precipitate pathway, used principally by the kelp-gatherers, but decidedly uninviting for those not accustomed to such ground. Such a point, quite out of the usual track of tourists, is but rarely visited, and I should not have had any knowledge of it had I not chanced to observe the remarkable cylindrical form when passing quite close to the shore in a boat, catching thus the bold outline presented by the eastern side of the rock form.

The cylindrical mass, known among the boatmen as the "*millstone*," occurs at the point of the promontory where the narrow spit joins the mainland. It here extends across the spit in an E.–W. direction, having a horizontal length of about fifty to sixty feet.

The section is not quite circular, being rather oval. The greater diameter, the horizontal one, is about twenty-four to twenty-five feet, and the vertical one about eighteen to twenty feet. It presents a series of apparently concentric joints, irregularly distributed as regards distance from the centre, and is furthermore broken up by radial jointing, also irregularly placed, and giving rise to blocks of forms very similar to those observable at the Causeway. The mass rests upon and is partially enclosed by an amygdaloidal basalt of the rich violet colour so remarkable in many of the beds along the coast, and characterized by the presence of masses of scarlet jasper wherever in contact with the sea water. This amygdaloidal basalt is much corroded, and is being

eaten away by the sea and atmospheric action, while the cylindrical mass seems to be of a much more durable material, and therefore to resist much better those corroding agents, although so extremely exposed by its advanced position.

Spherical and cylindrical forms in basalts and trachytes have been observed and described already. The cylindrical form, however, is the less frequent and less generally known. The spherical form has generally been explained to be due to hydration of the rock from the outside inwards, with consequent softening and final disintegration. The onion-shaped masses which occur in so many places about the Causeway and the coast afford excellent examples of this action.

The cylindrical form has not as yet been equally clearly accounted for. The only information or observation that I have met with relative to this form is contained in the remarkable Paper by Regnault, published in the *Annales des Mines* for 1832 (3rd series, vol. ii., p. 361.) It is entitled, "Sur les formations volcaniques du bord du Rhin, par M. Jean Regnault, Ingénieur des Mines." Speaking of the Wolkenberg, he says:—"Au milieu de la masse, ou trouve de vastes colonnes verticales de 50 à 60 pieds d'élévation qu'on ne saurait mieux comparer qu' à des troncs d'arbres; le trachyte se délite en feuillets minces et contournés, autour de l'arbre, comme une véritable écorce; à l'instant où nous avons visité la carrière, trois de ces colonnes très distinctement dégagées à moitié, s'élèvent sur toute la hauteur de l'escarpement."

Page 370. He mentions a lode or dyke of basalt:—"ayant sur les bords toute l'apparence de trachyte."

Page 371. "Vers la limite septentrionale du Siebengebirge on rencontre une grande formation de basalte courant à peu près parallèlement au Rhin, et qui forme une crête de près d'une lieue de longueur, son étendue et sa direction offrent quelques rapports avec les filons de basalte, N. et N. E."

He describes the form of the Langenberg, and states that the basalt, "est très dur, très résistant, fréquemment caverneux, avec géodes de calcite et arragonite." He continues:—"Mais la disposition générale qu'il affecte offre une singularité, dont on ne trouverait, je crois, que peu d'exemples; tout le Langenberg n'est qu'un fragment d'une vaste boule qui se délite concentriquement par rapport à un noyau globulaire, qu'on voit dans une carrière située près d'Obercassel. La carrière offre ce noyau avec toutes ses enveloppes sur une hauteur de plus de 100 pieds, et audessus et audessous dans la montagne et latéralement à de grandes distances, on voit les strates de basalte présenter la même connexion autour du centre commun; ce centre n'a avec la forme générale, aucun rapport géométrique. Il n'est pas inutile de faire remarquer que la courbure n'est pas celle d'une sphère, mais celle d'un ellipsoïde aplati."

Page 387. He discusses the probable existence of transitions or passages between the lavas, the basalts, the trachytes, and even the porphyries.

It is to be remarked, that of the two examples thus described, the one is a vertical form in a trachyte rock, whilst the other is a horizontal form in a basalt; moreover, its direction is connected with that of the basalt dykes of the district.

M. Regnault attributes the cause of the forms to alterations of the rock mass, with accompanying exfoliation, but does not examine the question whether the rock was or was not originally homogeneous, and how far the absence of homogeneity in the basaltic and trachytic masses, and the consequent different rates of cooling and solidification which must have depended on that absence of homogeneity, induced subsequent jointing along certain lines.

Now, no mass of molten or fluid matter when in movement, and in contact with bodies differing from it in temperature and in composition, can remain quite homogeneous or have all its parts equally warm, and therefore, so long as it remains fluid and in movement, there must be a tendency to the formation of a more or less regularly banded structure, which would guide and even assist subsequent alteration of the rock, particularly by the action of water.

It is upon these considerations that I propose to base an explanation of the cylindrical form in question.

When columnar basalt is carefully examined on the cross section, lines or bands of structure may be frequently observed, generally parallel to the sides of the block, but not unfrequently whorl-shaped or wavy. This structure may be mainly due to hydration, but it may also be connected with the original fluid state of the mass, and with the relative rates of solidification of the different parts. We have as an example the flow-lines in large masses of cut glass.

As regards the basalt of the north of Ireland, we have every reason to assume that they came up to surface in the joints resulting from previous dislocation, and thence spread into and on the adjacent rocks. Those joints traverse rocks of various constitutions, representing lavic, crystalline, and sedimentary series. These rocks vary amongst themselves, as regards thickness, constitution, and states of aggregation. They were differently affected by the force having produced the joint; and it is but reasonable to assume that the joint varied in outline according to the nature of the rocks traversed.

When, therefore, the basaltic dyke mass was fluid and in movement, it was continuously in contact with those containing rocks, and was acted upon by them in three ways:—

1. By the cooling of the basaltic fluid, from the sides towards the central axis, and the consequent tendency to banded structure thus induced.

2. By the mechanical derangement of the conditions of regular flow, wherever an enlargement or a contraction occurred in the section of the joint, and by the retardation of the flow along the walls.

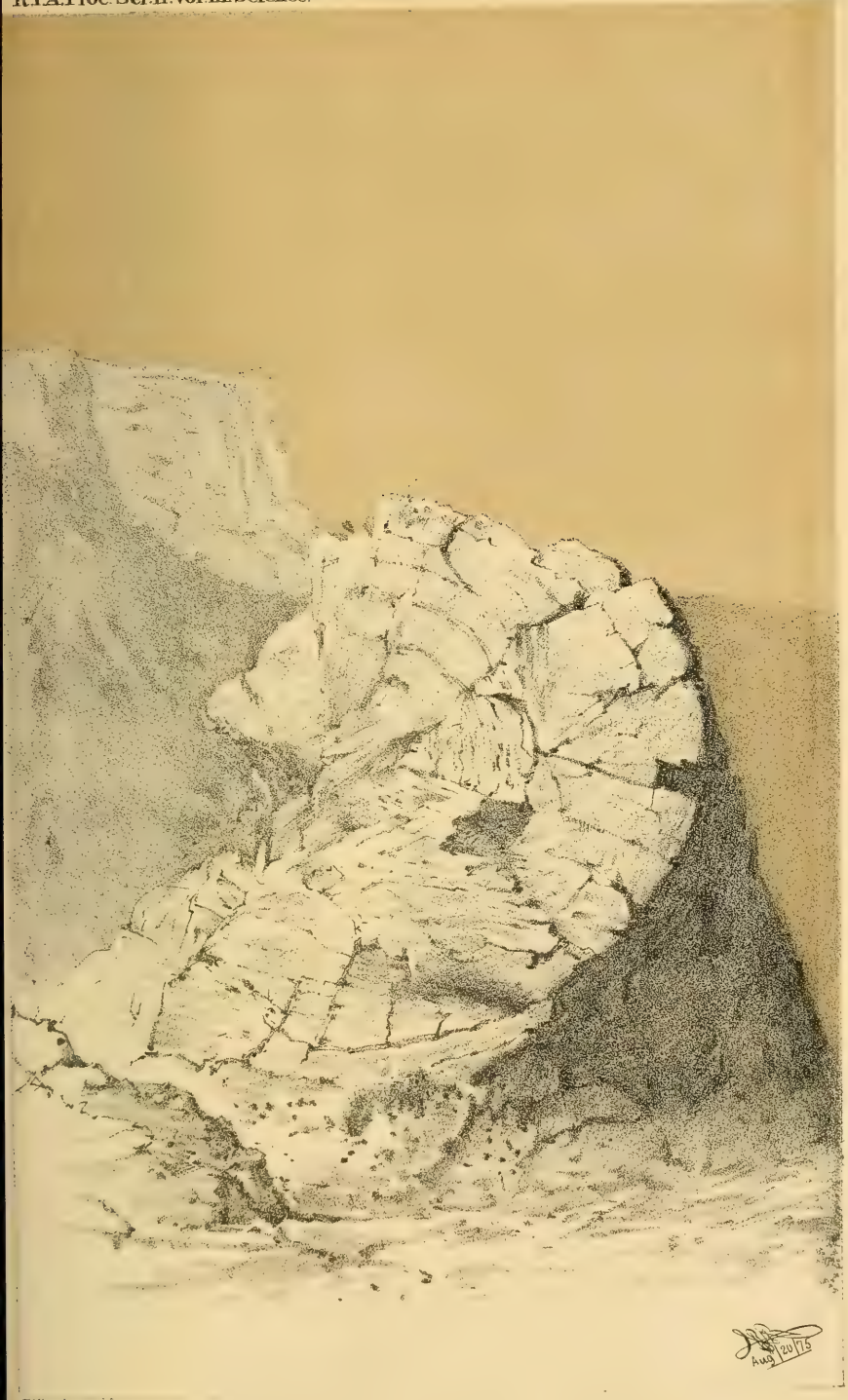
3. By the chemical reactions taking place between the fluid mass and such beds as were capable of being acted upon.

If the breadth of the joint remained quite uniform and unacted upon, the only action of the walls on the fluid mass would be that of reducing the temperature (wherever that temperature had not already attained that of the basalt). The differences of temperature thus produced should give rise to banding more or less defined and regular. Where, however, the section of joint presented an enlargement or a contraction, there not merely banding, but the formation of whorls, must have to some extent resulted, the fluid mass continuing in movement. Where the enlargement or contraction was very marked and sudden, then such whorls would have been most likely to be formed, and should, if formed, present a direction parallel to the intersection of the joint with the direction of the bedding. As, however, banding is assumed to have been going on simultaneously, the whorl should present, when solidified, lines indicative of that banding, the final cooling and solidification giving rise to the radial jointing. Those whorls would have tended to increase in diameter or number of bands with the persistence of the flow, and, moreover, would tend to uplift the strata or beds traversed by the joint, and at least to open the planes of bedding limiting such beds. Injection of the fluid basalt into those planes of bedding would thus be set up, and might continue, according to the conditions of pressure and of fluidity. There would thus be established a connexion between the dykes, their direction, the whorls, and the intercalation of beds of basalt between the previously existing beds traversed by the joint. Such a connexion is to some extent implied by the description given by Regnault of the Rhine basalt mass of Langenberg. It really exists in the case which I am discussing, since the direction of the cylindrical mass is that of the coast line, itself dependent on the jointing of the country.

There is a further and very interesting consideration in connexion with this whorl form, if it be admitted to have been formed as suggested. It is that of the temperature and of the correlative depth from surface at which the whorl was formed. Admitting for the fluid basalt a very slow movement, it is quite clear that the formation of the whorl would be equally slow, and even might be slower, and that the cooling should have been very slow indeed to allow of the continuous formation of one of those cylindrical masses. Such a condition of temperature would best be satisfied by the action having taken place at a relatively great depth, that is to say, a depth corresponding to that at which basalt melts, which may be taken at 700° or 800° C. at least. Or, by supposing that the fluid mass had remained in the joint such a length of time as to communicate to the sides an amount of heat sufficient to allow of a continuous movement in the mass without rapid cooling and solidification ensuing. In any case a certain depth from surface may be assumed as having been one of the conditions attending the formation of the cylindrical mass in question.

That the coast of Antrim has at some time been under the present level is sufficiently proved by the geological strata existing there.

West View of the "Mill-stone," Contham Head, Port Moon, Co. Antrim.



East View of the "Mill-stone," Contham Head, Port Moon, Co. Antrim.

That there have been many oscillatory vertical movements is more than probable, and every fact tending to prove those oscillations is of interest geologically.

I naturally sought for further confirmation of my views as regards the mode of formation of those cylindrical forms and their connexion with the basalt dykes, and I am under the impression that the bold mass of rock which rises from the sea at the entrance of Portroon Creek, half a mile west of the Giant's Causeway, and which I have sketched, affords such a confirmation. The dyke is perfectly distinct, with its transverse columnar formation, and presents, in my opinion, a whorl or cylindrical mass immediately in connexion with it. The distinctness of the form is not, however, so evident as to allow of my comparing it with the mass at Contham Head, but merits, however, being recorded as a term of comparison.

XL.—Notes of some Observations on Nitrification. By Edmund W. Davy, A. M., M. D., Professor of Forensic Medicine, Royal College of Surgeons, Ireland, etc.

[Read, May 12, 1879.]

A good deal of attention, on the part of chemists, has of late been given to the subject of nitrification, or the formation of nitrites and nitrates under different circumstances. This has arisen, in a great measure, from the observations of MM. Schlœsing and Müntz,[1] which were laid before the Academy of France about two years ago. From the researches of those gentlemen, they arrived at the conclusion that nitrification was due to an organised ferment, and that it was probably the office of some of the low forms of vegetable life to produce those oxides of nitrogen under different circumstances. And the subsequent investigations of Warrington, Storer, and of other chemists, would appear to go far to confirm the correctness of their theory of nitrification, at least under the conditions in which their experiments were made. Though there exists, no doubt in many cases, an intimate relation between the formation of nitrites and nitrates, and the development of certain organized germs, still as far as my observations go, I do not think that there is sufficient proof to show that their development in such instances is the cause of nitrification, and not, rather, one of the circumstances attendant on that process.

My experiments, however, were made not with a view to determine that question, but in reference to the detection of animal impurities in potable waters, and to ascertain the circumstances which were favourable or otherwise to the formation of nitrites and nitrates in waters which were so polluted, as the presence of such salts is generally regarded as indicating previous sewage contamination, and the drinking of water with such pollution is not only injurious to the health of those who thus employ it, but there exist strong grounds for the opinion which is now very generally entertained, that such water frequently becomes the means of conveying the germs of certain formidable diseases, especially those of typhoid fever and cholera, from its containing the fecal and other emanations of individuals labouring under those maladies, and thus disease and death are often insidiously brought into many homes when such diseases are prevalent in different localities.

Besides, as the formation or production of nitrates is one of great industrial and agricultural importance, any facts which might directly or indirectly enable us to facilitate or hasten that process would be of much practical value.

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[1] "Comptes Rendus," lxxxiv. 301.

As human urine and feculent matters may justly be regarded as the most offensive and dangerous ingredients of sewage in general, my experiments have been confined to those matters, and were principally made on urine, which, from its containing different nitrogenous substances, readily susceptible of decomposition, is peculiarly suited for the study of the nitrification of animal matters. By mixing this liquid with various proportions of water, and placing the mixtures under different circumstances, I have endeavoured to ascertain those that were favourable or otherwise to their nitrification; and to determine some points connected with that process which required further investigation. I should here observe that in detecting the occurrence of nitrification I have principally used the well-known test of Price for nitrites, which consists in adding to the water or mixture a thin solution of starch, containing a little iodide of potassium, and acidifying with diluted sulphuric acid, when a blue reaction from the liberated iodine will be immediately produced, should a very minute quantity of a nitrite be present. And as there is every reason to suppose that the production of nitrites precedes that of nitrates in the nitrification of organic matters in solution, and the detection of the former is much more easily effected than the latter, at least under the conditions existing in my experiments, I was satisfied in most cases to obtain the evidence of the formation of nitrites by the employment of the test to which I have just referred.

The experiments of Warrington[2] have led him to conclude that darkness is an essential condition to the development of those low forms of vegetable life, which are supposed in many instances to give rise to nitrification.

This is a question which it is difficult to determine decisively one way or the other, owing to the impossibility of having with us continuous daylight to operate with. Still I think we may arrive at an approximative conclusion on this point, by making comparative experiments on similar mixtures, kept altogether excluded from the light, and on those exposed to its full influence, and then determining the amount of nitrification which had taken place in each, after a given time; and if darkness be so essential to that process, we should naturally expect that in the mixtures exposed to its continuous influence there would be an earlier and a greater development of nitrification, than in those which had been placed under it for about one-third or one-half the time, each day of twenty-four hours.

From the results of several comparative experiments made in this way, I have come to the conclusion that the conditions of light or darkness exercise but little influence one way or the other in this process, at least under the circumstances existing in my experiments,

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[2] "Journal of the Chemical Society," January 1878.

which consisted in placing different portions of the same mixtures in similar bottles, some of which were surrounded with black cloth or velvet to exclude light, whilst others were left uncovered, and all of them were suffered to remain open or uncorked. On examination after a few days there was but little difference as to the amount[3] of nitrification that had taken place in each—indeed in some of my experiments it had progressed to a greater extent in the uncovered than in the covered bottles; and in all made on this subject (except those to determine this point as to the necessity or not of darkness), the mixtures were left exposed to the light, and some to the full influence of strong sunshine, yet still a considerable amount of nitrification took place in each. Besides, in nature much of the nitrates which occur in the surface soils of different localities must have been formed under the influence of more or less daylight; all of which facts, I conceive, are more or less opposed to the necessity of darkness in this process.

Another point which has not, I believe, been clearly established, at least as regards nitrification occurring in water containing organic matters, is the necessity of having a certain amount of air or free oxygen to carry on the process; this I have proved in the following very simple manner:—To water which had been kept boiling for some time to expel its contained air, I added a small quantity of freshly voided urine (the proportion employed being about one part of urine to sixteen parts of water, such a mixture having been proved to be very suitable for nitrification), and then repeated the boiling to ensure the removal, as far as possible, of any dissolved air. Several bottles which had been kept immersed in the boiling mixture were then filled completely with it, corked, and sealed with sealing-wax, to prevent the access of air. Some, however, of them containing this mixture were left open for comparison. After leaving the bottles for a day or two in the same place, I first examined the open ones for nitrites, and when the test indicated the abundant formation of those salts, I opened one of those sealed, when not a trace of nitrites was discoverable in its contents; the remaining sealed ones were opened at different periods subsequently, with the same results. Other comparative experiments were made, where the temperature of the mixtures was artificially kept at a heat very favourable to nitrification, but, in every instance where the access of air had been excluded, no trace of nitrites could be detected—clearly proving the necessity of more or less air or free oxygen for their formation. But the amount necessary to commence, at least, the process is small, for I found where

[3] In ascertaining the amount of nitrification, the indigo process as described by Sutton in his "Volumetric Analysis" was employed, which served for the determination of the nitrites and nitrates collectively; and though it may not be quite so accurate as some other methods, was sufficiently so for this purpose, as it was only the comparative amounts of nitrites and nitrates formed under the different circumstances of the experiments that I wanted to determine.

the mixture had not been boiled previously to the complete filling, corking, and sealing of the bottles, that the air dissolved in the liquid was sufficient to cause the production of nitrites to some extent.

The quantity of animal matter which is held in solution in the water, I find exercises a considerable influence over nitrification; for where it occurs in very large proportion, there the process either does not take place at all, or is carried on much slower than in the more dilute solutions. This I have proved by comparative experiments with water mixed with different proportions of the same sample of urine, or of solution of excrementitious matter, where I found that nitrification occurred first in the more dilute mixtures; and that where there was much organic matter present, that the nitrites which might ultimately be formed soon afterwards disappeared again by their subsequent change or decomposition, whereas those that had been produced in more dilute solutions have remained unchanged for a considerable time.

But the circumstance which I have found to exercise the greatest influence over nitrification is that of temperature; for I have observed that in cold weather it is very slow in taking place, whilst in warm it is much quicker, and that by the application of artificial heat the process can be greatly accelerated. The correctness of this observation is borne out by the well-known fact, that it is from the soils of different hot climates that we obtain our chief supply of nitrates.

As to what may be the most favourable temperature for this process, I have not yet been able to determine, owing to the difficulty, as I am circumstanced, in maintaining continuously the same degree of artificial heat; but I have found that where the mixtures were placed where they were kept at a temperature which varied from about 70° to 80° F., that there, the process was carried on very quickly, and that nitrites were soon abundantly formed, whereas in similar mixtures maintained at lower degrees of heat, or at the ordinary temperature, not a trace of those salts could be detected in the same time, and that their presence was not discoverable till after a much longer period.

The foregoing observations have, I conceive, some important bearings as regards the contamination of water with sewage, and the evidence of such, derivable from the occurrence in it of nitrites and nitrates. For though the presence of those salts is undoubtedly in many instances an indication of previous sewage pollution, still their absence, taken by itself, cannot be relied on as a sure indication of the freedom of the water from such contamination. For the circumstances present may have either been unfavourable to the formation of nitrites and nitrates, or have produced their subsequent rapid disappearance—thus, for instance, the lowness of the temperature of the water may have prevented their formation, or the quantity of organic matter present may have interfered with their development, or have led to their subsequent change and disappearance. Such, amongst

other circumstances influencing the presence of those salts in water containing animal matters, will at once be evident; and their absence, unless accompanied by other indications of purity, cannot be relied on as a proof of the freedom from such contamination.

Before I conclude, I wish to call attention to another fact, which I have noticed in connexion with this subject, viz., the rapidity with which nitrites are sometimes formed in waters contaminated with sewage impurities. This is a subject of considerable importance in an analytical point of view, as I shall endeavour briefly to explain.

It is well known by those who have analysed potable waters, that the method which chemists now principally employ to ascertain their purity or otherwise is to determine the quantity of ammonia a given amount of the water will yield on distillation, both before and after the addition of a strongly alkaline solution of permanganate of potash. The first obtained is termed the free, and the second the albuminoid ammonia. The former is regarded as the representative of the nitrogenous organic matters previously existing in the water, which have undergone more or less decomposition, whilst the latter is produced by the action of the alkaline permanganate on those substances still present in the water. Consequently, the less of each that is furnished by a sample of water when so treated, the purer organically is it regarded, and the safer, other circumstances being similar, would it be for potable purposes. When lately analysing a sample of water that had been contaminated with sewage, to ascertain the amount of such pollution, which was afterwards the subject of an important legal inquiry, in my first trial I found that the water yielded a quantity of free ammonia which was equivalent to 0.970 parts of a grain per gallon, but, on repeating the determination a few days afterwards, it was discovered that it had fallen to 0.186 parts of a grain for the same quantity of water, or to less than one-fifth of the former amount; whereas the quantity of albuminoid ammonia yielded had slightly increased. This result as to the great decrease of free ammonia, which at first rather surprised me, I ascertained was due to the formation of nitrites, which had been developed to a large extent, in so short a time, at the expense of the free ammonia. Such being the case, if the water had not been examined till the date of the second analysis, and if the nitrites had not been taken into account, this water would have been regarded as containing much less free ammonia than it did, and consequently that the previous sewage contamination was less than it really was; this point is therefore one of some analytical importance.

It is right for me to observe, in connexion with this latter fact, of the decrease of free ammonia in waters by keeping, that long after I had made that observation I met with, in the *Chemical News* for March 2nd, 1877, a letter written by Professor Pattison Muir of Owen's College, in which he calls the attention of chemists to some observations his brother had just made in the laboratory of the University at Sydney, in which he had noticed that the amount of free

and of albuminoid ammonia, as determined by Wanklyn's process, varied very considerably with the time the sample of water had been kept; but neither of those gentlemen has offered (in the letter referred to) any explanation of the fact, further than that Professor P. Muir throws out the suggestion, in the case of the increase by keeping of the albuminoid ammonia, that possibly it might have been owing to the germs which have escaped decomposition by the permanganate, undergoing a gradual decomposition in the water, and that ammonia is one of the products of this process. Be this as it may, I have satisfied myself that the loss of free ammonia is often due to the formation of nitrites or nitrates, which are very rapidly formed under different circumstances. And as regards albuminoid ammonia, the very slight increase which I observed in my experiment was, I thought, very easily accounted for by my having in the second determination carried on the process of distillation somewhat further than in the first trial, and in this way the amount might be very naturally increased.

Finally, my observations that nitrification is greatly promoted by warmth might, I conceive, admit of some practical application in the manufacture of the nitrate of potash in the artificial nitre beds, especially in those of cold countries; and I am not aware that heat has hitherto been anywhere artificially applied to hasten or promote that important manufacture.

XLI.—On Recent Researches respecting the Minimum Visible in the Microscope. By C. E. Burton.

[Read, May 26, 1879.]

Investigations for the determination of the magnitude referred to in the title of this paper have been recently made by Dr. Royston Pigott, and by Professor Abbè of Jena. Dr. Pigott has accumulated a number of data relating to the separability of details in the images of distant objects formed by any combination of lenses which is both aplanatic and achromatic for the conjugate focal distances employed, and also of short focus, when those images are viewed by a similarly corrected compound microscope, the optic axes of both systems being carefully adjusted to coincidence.

It is plain that if we assume that the light proceeding from the distant object to the focus of the image forming combination, which combination we will designate as *A*, pursues its course in strict accordance with the law of refraction, and with it alone, that we can very readily determine the linear magnitude of any detail in the image found by *A*, from the magnitude of the corresponding detail in the object used (meshes of gauze, window bars, &c.), the rate of object to image being equal to the ratio of the corresponding conjugate focal distances respectively. Dr. Pigott has published measurements which, upon the assumption just stated, would prove that linear magnitudes of less than $\frac{1}{100,000}$th of an inch could be distinctly discerned, and yet further, that lines could be separately distinguished when their reduced interval was approximately equal to $\frac{1}{1,000,000}$th of an inch.

I have repeated Dr. Pigott's experiments with some slight modifications, and have found that with two opposed objectives the equivalent foci of which were respectively $\frac{1}{3}$th and $\frac{1}{4}$th of an inch, that the image of a fine line at a considerable distance was still visible when reduced to a magnitude equal, on the above supposition of a strictly geometrical reduction, to over a hundred and forty thousandth of an inch. Using a $\frac{1}{10}$th by Ross, and $\frac{1}{12}$th by Hartnack, as the image forming and examining objectives, the fine line used as object was visible as a *geometrical* magnitude = a two hundred and eighty thousandth of an inch, and appeared sensibly as distinct as when viewed under the same visual angle by the naked eye.

The deductions just made as to the linear magnitude of the images of the distant fine line are, however, shown to be untenable when we consider that we have no means, as far as is known at present, of ascertaining the form and dimensions of the details of an image produced in the manner above described, other than the optical examination of it with the aid of a system of lenses which would produce a precisely similar effect on the rays from the object if placed in a similar position to that occupied by the image forming system *A*. Let the examining system be designated *B*. Then the rays which have been converged by *A* to any area in the common focal plane of the two objectives will diverge again symmetrically from that area to *B*, and

supposing both combinations to be perfectly corrected, would form an image of the object precisely similar to it in the rear of *B*.

The effect of any interference or of diffraction in the convergent cone from *A* will be undone in the divergent cone whose base is the front lens surface of *B*.

Therefore, whatever be the actual distribution of light and shade in the common focal plane of *A* and *B*, the resultant after passing *B* will be identical with the originant, *i. e.* the object of *A*. In other words, *B* merely restores the rays to the identical mutual relation which they possessed before entering *A*.

The existence of any aberration in either or in both of the objectives or combinations of lenses used, *A* or *B*, disturbs the relation of symmetry between the convergent and divergent luminous cones, and consequently renders the restoration of their components to their primary condition more or less incomplete. The final image thus becomes indistinct to a corresponding extent, so much so indeed that the method of Dr. Pigott approves itself as an extremely sensitive detector of aberrations outstanding in the opposed systems.

But it is evident that no information as to the separability of material lines as distinguished from focal images can be obtained by the method just described. In the case of material objects, the light which renders them visible has undergone very different treatment from that adverted to above. Every system of material points, the intervals of which are comparable in dimensions to the length of a wave of light, acts as a more or less regular diffraction grating when a pencil of rays is transmitted through it, and the pencil is redistributed in the process of transmission into a direct pencil, and a varying number of diffracted pencils dependent upon the number of regular diffracting systems, of which we may conceive the assemblage of material points to be composed, and divergent from the axis of the undiffracted pencil at angles which are determined by the degree of closeness of the several imaginary component gratings. The angles of divergence of diffracted pencils increase with the fineness of the details producing diffraction until they approach equality (for direct light) to a wave length of that light when the divergence becomes equal to 90°, or, in other words, diffraction ceases.

If the angular aperture of the observing objective be sufficiently wide, it will receive one or more of these diffracted pencils besides the direct pencil.

Professor Abbè's researches have resulted in showing that the representation of minute detail of *any* kind is dependent on the admission of rays from these spectra to the final image in the focus of the eye lens of the microscope, and that if these diffracted pencils be entirely excluded from the final image no detail at all will be shown, but merely the outline of the object viewed, *e. g.*, the edge and midrib of a diatom; its markings, so called, being invisible. Furthermore, Professor Abbè has proved that the fine details of an object will be shown more nearly as they exist, the greater the number of

the diffracted pencils admitted by the objective. If the admission of these spectra is interfered with either by the limitation of the angular aperture of the objective used from its original construction, or by intentional screening off of any of the diffracted pencils which would otherwise reach the final image of the object, the apparent detail will be modified in a corresponding manner. These facts may be very readily and simply demonstrated, when a microscope furnished with an objective of one quarter of an inch equivalent focus is directed upon a valve of *Pleurosigma Balticum*, for example. If the objective has an aperture of 90° or thereabouts, there will be seen, after focusing and removing the eye-piece in order to look down the tube of the instrument, a brilliant image of the mirror or source of illumination, and symmetrically disposed round this direct image, if it occupies the centre of the tube, four similar but much fainter images, coloured red at their outer and fringed with blue at their inner edges, if white light be used.

These faint images are the diffraction images of the source of light, each being composed of separate monochromatic, and individually accurate, representations of the luminous origin, which are distributed along a radius, commencing at the direct image, and arranged in order of increasing wave length. The composite image is therefore somewhat distorted, being elongated in a radial direction, and fringed with colour as above described, from the overlapping of the extreme images.

If the luminous source be a narrow slit allowing a sufficiently bright pencil to pass through a system of diffracting lines parallel to itself, some of the Fraunhofer lines may be seen, if solar light be employed, especially if the eye be assisted by a magnifying glass focused on the diffraction images.

If now we conceal any two opposite spectra by appropriate screens, and replace the eye-piece, we shall find that one of the systems of lines with which the object is apparently marked has disappeared, namely, that which is at right angles to the line joining the concealed spectra. If while we still hide the same two spectra we also block out the direct beam, the system of lines last mentioned will be replaced by another, the components of which are at half the distance of those just described, and twice as numerous.

This fact points the way to the explanation of the varying phenomena, which attributes the visible systems of lines seen in the image of such an object as we have chosen to the interference of the rays from the images of the source of light formed in the upper focal plane of the objective, where they meet within the eye-piece.

The process of production of these interference striæ is as follows; tracing the course of the light rays from the origin upwards, and assuming them to be parallel.

In the annexed diagram (1), let *a*, *b* be the incident beam falling

[1] *Vide* Note added in Press.

perpendicularly on two elements of a grating which are represented in transverse section by the thick short lines *c d*. The lines *f f'* re-

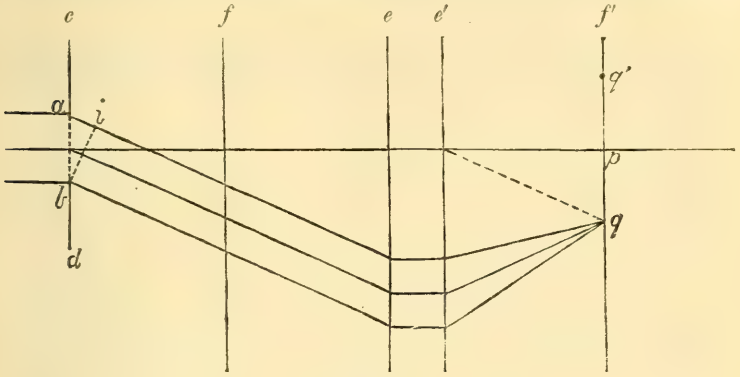

Diagram (1).

present the principal focal planes of the objective employed, and *e e'* the infinitely thin lenses which would produce refractions of the transmitted light equivalent to those actually caused by the objective itself; *p* is the point at which the light transmitted directly through the grating is brought to a focus. A bright line is consequently produced there if the source of light be a slit. But there will also be lateral diffracted rays, one of which is shown pursuing its course to a focal point in *q*. If *a i*, the difference in the length of the two sides of the beam, be equal to a whole wave length, the two sides will reach *q* in the same phase, and the result at *q* will be a bright line. If the difference in length of path be equal to only half a wave length, the result at *q* will be a dark line. In general, where the difference in length of path equals an even multiple of a half wave length, a bright line will be found in the plane of *f*; when, on the other hand, the difference equals an uneven multiple of the wave length, the result will be darkness.

Let α be the angle of inclination of the diffracted ray, λ its length of wave, and *a b* the breadth of the successive intervals of the grating, then we have for the first bright line $\sin \alpha = \lambda \div a\ b$; for the second bright line, $\sin \alpha = 2\lambda \div a\ b$, and so on. If light of a higher refrangibility, *i. e.*, of shorter wave length, be used, *q* and *q'* will be found nearer to *p* than before, because *a i* will have been diminished, and thus, if white light be employed, the image of the source formed at *q* and *q'* will be impure, and will appear fringed with colour, blue at the inner, and red at the outer edges.

If also the source of light be of sensible magnitude, the rays of each colour will form an infinite number of apposed images of the elements of its surface in and near *q* and *q'*, composing thereby perfect images which will overlay one another, and appear at each side

of the visible image in the plane f' as coloured edges, as previously mentioned.

We will now investigate the influence of these images, direct and diffracted, formed in the upper focal plane of the objective, upon the image of the *object* formed in the focus of the eye lens of the microscope, by the aid of diagram (2), in which B indicates the place of the real image of the object. Let a and a' be the direct and one of the first order of diffracted images of the source of light. The rays emitted from a and a' will interfere at B, and if the distances $a\,B$ and $a'\,B$ differ by a whole wave length a bright line will be produced; if the difference be half a wave length darkness will result. From centre a strike two arcs, one through B, the other through a point distant from B by a wave length. From a' describe a third arc through the point within B. The crossing point P of the two arcs marks where the undulations starting from a and a' are found to differ by a whole undulation, and consequently where the first bright diffraction line is situated. The sides of the small triangle whose apex is in P, though arcs of circles, are so short that they may be considered straight lines, and as this triangle is similar to the triangle $a'\,aB$, we have the relation

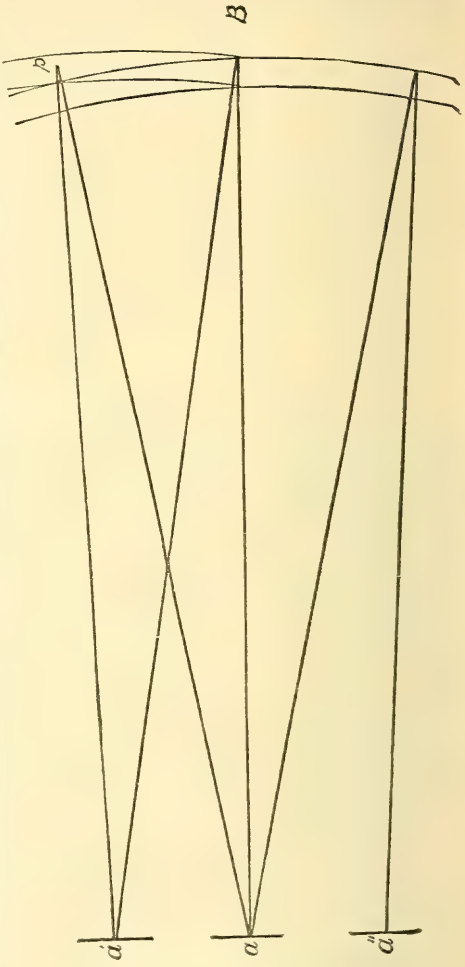

Diagram (2).

$$B\,P : \lambda = a\,B : a\,a';$$

or

$$B\,P = Ba.\lambda \div a\,a'.$$

Now Ba is = the conjugate focal length p' less the principal focal length f, or $p' - f$. Referring to diagram (1), we see that

$$a\,a' \text{ or } p\,q = \sin\alpha \,.\, f.$$

Since for the first diffracted pencil $\sin\alpha = \lambda \div d$, d being the distance of the striæ in the object, the above formula becomes

$$B\,P = \frac{(p'-f)\,.\,\lambda}{\frac{\lambda}{d}\,.\,f} = \frac{p'-f}{f}\,.\,d;$$

or, since

$$p' - f \div f = \text{the magnifying power } m;$$
$$\therefore B\,P = m\,.\,d,$$

i. e. the distance of the visible striæ in the real image of the object is equal in this case to the distance of the actual diffracting elements of the object multiplied by the magnifying power of the objective.

If the direct ray A is screened off, then the first of the equations just given becomes

$$B\,P = Ba\,.\,\lambda \div a'\,a'',$$

that is to say, since $a'\,a'' = 2\,a\,a'$, $B\,P$ is halved, or striæ will be seen, the intervals of which are half the intervals of the set seen in the first case. The reduction of the intervals of the visible striæ may be carried further by screening off all the spectra of the first, second, &c., orders.

It has been shown in treatises on Interference Phenomena that rows of dots, individually of any form whatsoever, will, if of sufficient minuteness, behave as if they were actual striæ, both species of intercepting systems producing identically the same phenomena. It matters not whether the dots in question consist of actual absorbing particles, of transparent elevations or depressions in a uniform membrane or shell, or of mere differences of refractive powers between adjoining portions of the same substance, the effect on the luminous undulations is the same in all cases of similar arrangement. All the markings seen on different species of diatomaceæ for instance might have been previously drawn by a person who had never seen a diatom in the microscope, had the grouping and distance *inter se* of the spectra seen at the upper focal plane of the objective been communicated to him. The diffracting obstructions originating the known appearances may belong to any of the classes just enumerated, but we do not know, and we never shall know *by mere microscopical inspection*, what the diffractive structures really are.

Lastly, it is easily seen that, as the visibility of minute detail depends on the diffraction spectra produced thereby, the limit of visibility is attained when diffraction ceases, or, in other words, when the angle α becomes equal to 90° for spectra of the first order. Referring to diagram (1), we see that this occurs when $a\,b = a\,i = \lambda$ of the light

employed, if homogeneous; always supposing that the aperture of the objective used equals 180°.

It is, furthermore, easy to show that if the incident light is as oblique as possible, the limit of visibility becomes $=\frac{\lambda}{2}$, or about 0·0002 millimeter, approximately = one one-hundred and twenty-five thousandths of an inch. Photography enables us to advance a little further into the unknown along this path, but the advance thus made is comparatively small.

Finally, I have to apologise for presenting to the Academy so rough a paraphrase of the work done in reference to this subject by Professor Abbè, and by MM. Nägeli, and Schwendener: my excuse is, that perhaps that work may thus be made known to some earlier than it otherwise would be.

NOTES ADDED IN THE PRESS.

I.—The diagrams (1) and (2) in the text are copied from Figures 125 and 128, at pages 222 and 226 of the 2nd German edition of Schwendener and Nägeli's work on the Theory and Use of the Microscope. Published by Engelman, Leipzig, 1877.

II.—It has been pointed out to me that the incapacity of the direct pencil for representing minute detail should be explained in few words, as the explanation has been omitted by the writers mentioned above. An object can give rise to a visible shadow only when the portions of the luminous wave which spread into the geometrical shadow destroy each other wholly or in part by interference, in consequence of the length of their paths differing by an uneven multiple of half an undulation. As the light which passes by the edges of a given microscopic object proceeds from the luminous source, it is in the same phase of undulation throughout at that passage, and consequently the secondary waves which bend into the geometrical shadow cannot interfere to produce a real shadow, unless the difference of the length of the lines imagined to be drawn from the edges of the object to any point of its geometric image be at least half an undulation of the light employed. If it is less than that quantity, the whole of the geometric shadow will be filled with light, and the object will be invisible. This applies to objects of any form or magnitude disposed in any manner whatsoever, and to ordinary, as well as to assisted vision.

XLII.—NOTE ON THE METEORS CONNECTED WITH THE FIRST COMET OF 1870. By J. L. E. DREYER, M. A.

[Read, June 23, 1879.]

IN November, 1873, I published in the *Astronomische Nachrichten*, vol. lxxxii. No. 1963, a note on some minor radiant points of shooting stars which are in activity during the beginning of August, and which seemed to be connected with the first comet of 1870. For this comet I had the year before computed the orbit, based on a discussion of all the available observations,[1] and from this orbit I found the radiant point of the comet to be

$$\alpha = 27^\circ\ 51', \quad \delta = +\ 48^\circ\ 24',$$

while the comet in its descending node (which the earth passes on August 14) was only 0·014 distant from the ecliptic, the mean distance of the earth from the sun being unity.

This note has apparently not attracted the notice of the committee on luminous meteors of the British Association, as the radiant of the comet I. 1870, in the "Reports" for 1874, 1875, and 1878, is given as $\alpha = 43^\circ{\cdot}5$, $\delta = +\ 53^\circ$, which position, as well as the date (August 12), is unquestionably wrong.[2] The conclusions based on this erroneous radiant point are therefore, of course, also wrong. In my note in the *Astron. Nachr.* I had only mentioned the following three actually observed radiants of meteors as being in pretty good accordance with the computed radiant of comet I. 1870 :—

August	3	$\alpha = 35^\circ$	$\delta = +\ 44^\circ$	Zezioli,	No. 132
,,	11	24	58	,,	,, 141
,,	3–12	31	55	J. Schmidt,	,, 46 (A.N. 1756).

Since then, however, the following positions of radiant points have been published in the "Reports" of the British Association :—

Aug. 10	(1868)	$\alpha = 33^\circ$,	$\delta = +\ 59^\circ$	(Forbes, "Rep.," 1874, p. 334).
,, 9–12	(1872)	33	57	(Italian obs.—see *The Observatory*, vol. ii. p. 165).
,, 8–11		25	59	(Lorenzoni, "Rep.," 1876, p. 160).
,, 10	(1876)	33	56	("Report," 1876, p. 154).
,,	(1876)	31	59	(Denning, "Rep.," 1877, p. 176).

The cluster χ Persei ($33^\circ + 56^\circ$) is often mentioned as a radiant of meteors—*i. e.* by Mr. Clark of York ("Report" for 1877, p. 158), and by Mr. Denning, who finds a group of stationary meteors at $32^\circ + 57^\circ$.[3]

Whether the above radiants are all identical or not, we have here to do with a phenomenon entirely distinct from, though similar to, the great annual star-showers which bear the name of the Perseids, and

[1] *Astronomische Nachrichten*, Vol. lxxx. No. 1910.

[2] In a separate copy of the Report of the committee on luminous meteors for 1878 (placed in my hands by Dr. Ball), Prof. Herschel has corrected the position to $25^\circ{\cdot}5 + 45^\circ$, which comes nearer to the true position.

[3] "Monthly Notices," R. A. S., xxxix. p. 407.

move in the same orbit as the great comet III. 1862. The orbit of the comet I. 1870, appeared at first very like that of the last-named comet; but my final determination of the orbit gave elements less like those of the Perseid comet. All the same, it is very interesting that the two comets show their meteors almost on the same days, and the aphelia being pretty near each other, the whole system of comets and meteors form one of those "comet families," of which the researches of M. Hoek have found so many instances.[4]

Subordinate radiants do not only appear in the case of the Perseids: there are a good many such groups of radiants known. There are two ways in which such neighbouring radiants may have originated: either a great accumulation of meteors moving in the track of a comet may have been disturbed by the earth at some distance from it—great enough to prevent the swarm from being scattered, and yet small enough to make it move in a new orbit;—or the attraction of the earth on the single meteors, which pass us closely, may make the orbit have a number of radiants instead of a single one. The curve, which a meteor will describe round the earth, is a hyperbola, the asymptotes of which are two lines in the directions in which the meteor approaches and leaves the sphere of attraction of the earth. When we pass through a swarm of meteors, the earth is therefore perfectly enveloped by such hyperbolas, along which the meteors will move in all directions, instead of going in parallel orbits, as they did before meeting the earth. Once, therefore, a certain meteor has passed close by the earth, it cannot, if the orbit is a closed curve, and we meet it a second time, appear to come from exactly the same point in the heavens—in other words, the radiant will be slightly different. According to Oppolzer, the time of revolution of the great comet of 1862 is 121 years. If, then, the Perseus-meteors are particles which gradually have been separated from the main body or nucleus of the comet by evaporation of the parts nearest to the sun, and by the subsequent condensation of these vapours into a number of small bodies, the main stream of these would be surrounded by a number of scattered bodies, moving in orbits more or less different from that of the main stream, and these straying meteors would, it appears, produce the phenomena of secondary radiants.

It does not, however, seem likely that the meteors, which radiate from a point near χ Persei, have originated in this way. As the radiant is so near that of the comet I. 1870, the elements of which are not a little different from those of the comet of 1862, it seems probable that the two meteor-showers are independent of one anotehr, each being composed of matter left behind by its mother-comet. But, besides the meteors from near χ Persei, there are many other Circum-Perseid meteor-showers, as amply shown by Mr. Denning (Brit. Ass. "Report," 1878, p. 344); and it appears likely that at least some of these have arisen from the perturbations caused by the earth, as described above.

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[4] "Monthly Notices," R. A. S., xxv., xxvi.

XLIII.—CONTRIBUTIONS TO THE STUDY OF NERVE-ACTION IN CONNEXION WITH THE SENSE OF TASTE. I.—FUNCTION OF THE TRIGEMINUS. By GEORGE SIGERSON, M. D., CH. M., F. L. S.

[Read, June 23, 1879.]

IT is a remarkable fact that, whilst the study of some of the special senses, such as those of sight and hearing, has made great progress, that of the sense of taste remains still in a very imperfect condition. The difficulties in the way of its elucidation are evidently considerable, for we find that contradictory results have been arrived at by various observers of repute. Unquestionably much advance has been made since the physiological doctrine, as stated by Boerhaave and Duverney, was in unison with popular opinion, in regarding the tongue as the only seat of taste. De Jussieu, disturbing that concordance, placed physiology on the true path of research when he pointed out that taste was still preserved after the excision of the tongue, and that it was present in those from whom the tongue was congenitally absent. These pathological facts proved, not of course that the tongue was devoid of this special sense, but that other parts within the buccal cavity possessed the power of distinguishing sapid impressions. When, however, it became a question of differentiating and localising the taste-power, the difficulties increased with the accumulation of facts. Hence, even at the present day, most points of importance in connexion with this subject should be looked upon as still in dispute, if we are to accept the statement embodied in the most recent edition of a standard physiological work. Professor Hermann[1] of Zürich, having mentioned that it is difficult to separate the taste-sense from simultaneously evoked odorous and tactual sensations, and to strictly localise the test-fluid, makes the following statement:—"The special seat of the gustatory sensibility has therefore been very differently stated. Undoubtedly, the root of the tongue plays an important part, but it is doubtful whether it alone (Bidder, Wagner), or also the tip and the borders of the tongue (Schirmer, Klaatsch, Stich, and Camerer), the soft palate (J. Müller, Drielsma), or at least a part of it (Schirmer, Klaatsch, and Stich), or even the hard palate (Drielsma), are seats of gustatory sensation."

The method of research by means of physiological experimentation on animals affords us only a limited assistance; for, as animals cannot give us an intelligible expression of their sensations in this matter, the results obtained are often unsatisfactory, and have sometimes proved misleading. Undoubtedly many valuable facts have thus been acquired, but it seems almost impossible, by this method, to distin-

[1] Hermann, *Elements of Human Physiology*, p. 458, London, 1878.

guish properly, for instance, between degrees of impairment in the taste-sensations of different sapid substances.

Disease is the most skilful vivisector. It can stimulate to excess a given nerve, and enable us to observe the result; or, by paralysing it, disease can render the nerve wholly inactive, and thus withdraw a factor, leaving us to determine its function by observing the consequences of its absence. In presence of so complex a problem as that before us, it is obvious that the sources of possible error of observation are many. Hence, unless where the attention of the observer has been specially directed to determining the topography of taste, it is impossible to accept the recorded results as satisfactory. Thus, frequently, if not generally, in ordinary practice the patient is allowed to withdraw the tongue before signifying whether or not he perceives a taste. In such cases, we can come to no conclusion against a localised abolition of the sense, inasmuch as the withdrawal of the tongue, and its subsequent motion within the buccal cavity, will bring the sapid substance in contact with regions where the taste sensation is still preserved. Where precautions have not been taken, with special reference to such dangers, the statement of a positive result cannot be taken as really excluding the presence of a localised paralysis of taste—say, for instance, in the anterior border of the tongue. Or, if the substance be aromatic, its presence may be recognised (ex hypothesi) by the olfactory sense alone, and yet the patient's declaration that he tastes it may be recorded as an instance of the conservation of the gustatory sense. Non-attention to these sources of error has been the cause of the reception of many of the contradictory results which help to obscure the study of this subject.

Hence, a simple enumeration of recorded results does not, of necessity, increase the weight of evidence, with reference to disputed points, unless it be manifest that the observers who recorded them had their attention particularly directed to the elements of the problem. Such examples have an exceptional interest, and are of great utility, when employed to control and verify the results of a physiological experimentation on animals.

With the desire of adding something to the exact study of this important question, I venture to submit the following observations which have a direct bearing upon the action of some nerves, and indirectly serve to elucidate the function of others.

I.

1. *Function of Palatine Nerves.*—The facts which I have observed relate to the soft palate. The innervation of this region is somewhat complex. The anatomical investigations of M. Debrou, and the physiological experiments of Dr. Volkmann, go to prove that it receives branches from the glosso-pharyngeus, which supplies the levatores palati and the azygos uvulæ. This is a mixed nerve, and its galvanization demonstrated, by inducing contraction of these muscles, that

it furnished them with motor twigs. It is presumed that sentient fibres are sent to the mucous membrane. The circumflexus or tensores palati receive motor twigs from the inferior branch of the trigeminus, contracting when it is stimulated. Again, stimulation of the pneumogastric, a mixed nerve, induces contraction in some of the palatine muscles (Bischoff and Reid). From Meckel's ganglion, the spheno-palatine (which receives its sensory supply from the superior maxillary, or second division of the trigeminus), some branches proceed to supply the hard and soft palate, tonsils, and uvula. Of these the anterior palatine branches are described as sensory (Robin), whilst the posterior are mentioned as destined for the levatores palati and azygos uvulæ. A pterygo-palatine branch supplies the mucous membrane of the Eustachian tube, and that of the adjacent nasal and pharyngeal region. The otic ganglion (Arnold's) receiving a root from the inferior maxillary (said to be its motor supply), receives also in its long slender root (Arnold's minor superficial petrosal nerve) a supply from Jacobson's nerve which brings the glosso-pharyngeus into communication with the trigeminus. It is asserted, however, that the branches given off from this ganglion (which they merely pass through) come from the motor portion of the trigeminus; they supply, according to Robin, the levator palati, the internal pterygoid, and tensor tympani. It does not appear to me to be demonstrated that only motor branches are given off to the palatine region. Professor Hermann, having stated that the otic ganglion gives off two branches, one to the tensor tympani, and another to the tensor palati, remarks: "The physiological importance of this little centre is, however, in all probability, much greater than one would conclude from the fact of its merely giving off these two small muscular branches, as it is probably through it that the fibres of the facial, contained in the small superficial petrosal nerve, make their way to the auriculo-temporal nerve (5th), and thence to the parotid gland, for which they are most probably secretory. Further, it is probable that, through the otic ganglion, fibres of the glosso-pharyngeal, derived from its tympanic branch, make their way to the facial nerve."

Incidentally, the importance of this ganglion, as a connecting junction, will be illustrated by the facts of the cases which follow. In the first case, a patient affected by a pontine lesion had complete facialis paralysis on the left side of the face. On that side, however, the sense of hearing remained perfect, and the sense of taste was left intact which would not be the case if, as some have asserted, the facial nerve shared in it. On the right side there was paralysis of the inferior maxillary branch of the trigeminus. There was, consequently, absence of sensation in the external ear and integuments of the lower jaw. Thus, owing to the anæsthesia and analgesia, the patient did not feel the razor whilst shaving, and sometimes cut his cheek without his attention being aroused by pain. There was a certain degree of diminution of the senses of taste and touch observed on the right anterior portion of the tongue, the cause of which I shall discuss

further on. Besides the unpleasant sensation of "dead numbness," as the patient called it, which affected the external ear, down through the meatus, there was marked loss of auditory power. In order that he should hear the tick of a watch it was necessary that it should be applied close to the ear. This defect came on simultaneously with the anæsthesia of the inferior maxillary nerve, and passed away as the latter began to improve. The progress was different from that I obtained where the auditory nerve was itself affected. It seems impossible, therefore, not to connect these two facts in relation as cause and effect; the paralysis of the inferior division of the trigeminal nerve inducing a degree of deafness corroborates the opinion of M. Robin, who states that the motor branch, derived from it, simply passes through the otic ganglion to supply the internal muscle of the malleus.

This connexion being made clear, I pass to the second case. In this instance, a young patient came to me, complaining in almost the same terms, of deafness and unpleasant numbness in the right ear. It was necessary that the watch should be quite close to his ear to enable him to hear it ticking. Sensation was, however, intact over the face. On examining the throat I at once perceived a relaxation of the palatine muscles on the same side; and further tests showed that I had before me a strictly localised paralysis, affecting the nerve-branches which proceeded from the otic ganglion to the tympanum, on the one hand, and to the palate on the other. The spheno-palatine nerves could be excluded, for the region supplied by their anterior branches (described as sensory) was not affected by the paralysis, and there seems no probability (nor does it, indeed, matter to the question) that the posterior muscular branches were affected.

This localised paralysis afforded an opportunity of studying what changes, if any, resulted in the palatine region supplied by the nerves affected. As one-half only of the soft palate was involved, an immediate comparison could be made, in the same individual, between the results of tests applied on both sides.

It was obvious, in the first place, that motor filaments had been supplied, and were paralysed: but is the statement accurate that the nerve-supply is purely motor? That, I may say, seems at the outset a somewhat gratuitous assertion, considering the character of the otic ganglion. The pathological facts observed in the palatine region in consequence of this localised paralysis were the following:—

1°. Motor paralysis of certain muscles supervened;

2°. There was loss of heat-sense—the patient not being able to detect the heat of a warm gargle on the affected side;

3°. There was marked loss of the sense of touch;

4°. Sense of pain was very greatly diminished;

5°. Finally, as regards the sense of taste, the existence of which in the soft palate some have contested, I found that it unquestionably was present on the healthy side, and that it was almost, if not quite, abolished in the paralysed half of the palate. When test-fluids,

which were not perceived on this side, were drawn across the mesial line, there was an immediate contortion of the face.

It follows, from the foregoing facts, that the nerve-supply proceeding from the otic ganglion is sensory as well as motor; sentient filaments of the fifth, and possibly loan-fibres of the glosso-pharyngeus accompany the motor nerves to the palatine region.

II.

Function of the Lingual Nerve—The function of the lingual branch of the trigeminus has been a subject of dispute, especially since Pannizza of Pavia denied, in 1834, its connexion with the sense of taste, which he considered to be under the exclusive sovereignty of the glosso-pharyngeus. According to his view, the lingual was solely concerned with the tactual sensibility of the tongue. Magendie, five years later, propounded a doctrine which was the exact contradictory of this opinion; for he maintained that the lingual is, and is exclusively, a nerve of taste. Against this it is asserted that he must, in operating, have mistaken a pharyngeal branch of the pneumogastric for the glosso-pharyngeus, and that he, consequently, drew his conclusions from faulty premisses. More trustworthy testimony against the contention of Pannizza is to be found in the experiments of J. Müller, and especially in the later experiments of my friend Professor Schiff, of Geneva. The result of their researches goes to prove that taste is not quite abolished when the glosso-pharyngeus is divided, though it is greatly diminished. It is true that the animals operated on (dogs and cats) did not refuse to lap milk with which colocynth had been mingled; but, on the other hand, when pure milk was placed alongside of milk so prepared with a bitter, they displayed a distinct preference for the former. This would appear to demonstrate that the trigeminal nerve-supply is capable of conveying gustatory sensations of some kind. Hirschfeld and Valentin, however, have supported the opinions of Pannizza on anatomical grounds. Various experiments have shown that, of the anterior part of the tongue, the dorsum is scarcely, if at all, susceptible of receiving taste-impressions, whilst the edges and point are sensitive to them. Hirschfeld and Valentin maintain that the difference is due to the anatomical fact discovered by them, namely, that an external branch of the glosso-pharyngeus proceeds along each margin of the tongue to the tip. Hence, they hold that Pannizza's view still remains the correct one, asserting that the glosso-pharyngeus is the sole nerve of taste. Their adversaries, however, declare, on the other hand, that as the lingual nerve sends a recurrent branch to the base of the tongue, the sensibility to sapid impressions existing there, which has been referred altogether to the distribution of the glosso-pharyngeus, must be claimed for the lingual nerve.

I may here point out that, if either of these doctrines be accepted, and it be granted that the sense of taste is the exclusive appanage

of one or other of the nerves named, a new and considerable difficulty would arise. Several physiologists, amongst them being Vernière, Admyrauld, Longet, Neumann, and Rosenthal, have made experiments with a view to localise the different kinds of sapid impressions. The general result, so far as the tongue itself is concerned, seems to be that the base is sensitive to bitter impressions, and the edges and point to saline, sweet, and acid savours especially.[2] Now, if the same nerve supply both regions, it is obvious that this remarkable difference stands in need of an explanation. Of course, such a difficulty as this could not exist if we accept the opinion of HH. Bidder and Wagner that the root of the tongue alone, and not the edge and point also, is sensitive to taste-impressions. But whilst this view is in contradiction to that of most experimenters, and indeed to general experience, it would only displace one difficulty in order to substitute another; for if it be hard to conceive that the same nerve should not receive a bitter savour in the anterior part of the tongue whilst it does perceive it at the base, it is still harder to understand how it should receive all taste-impressions at the base, and reject them all in front.

Such being the state of the question, in which almost everything is yet under litigation, I venture to offer for consideration the following facts, which, I hope, will help to elucidate the action of the lingual nerve. Pathology, in this instance as in others, may lend its assistance to experimental physiology, and, by removing a factor, enable us to understand, by the consequences of its absence, the function which it fulfilled when in activity.

The pathological facts were observed in a case which, owing to the peculiar nature of the lesion, was exceptionally well adapted to present them with clearness, and to permit of comparison and verification. The lesion occupying a position in the bulbar region of the pons varolii, complete paralysis of the facialis nerve had supervened on the left side of the face, whilst on the other this nerve was unharmed. Here, however, on the right side, the third or inferior maxillary branch of the trigeminus was paralysed, with result of depriving the cutaneous surface of the corresponding region of its normal sensibility to touch and pain.

When the condition of things in the interior of the buccal cavity is considered, it will be remarked that a rare opportunity was presented of ascertaining the functions of the nerve-supply derived from the facialis, and the trigeminus, inasmuch as the former was eliminated as a factor from the left, and the latter from the right side of

[2] Pathology supplies facts which tend to accentuate this difference. Thus, in the case of a patient affected with aphonia, sweet mixtures were rejected and "could not be taken," whilst bitters were readily accepted. This would appear to indicate that there are special fibrils for the conveyance of different sapid impressions, and that they may become subject to hyperæsthesia. Numerous instances could be given in which intolerance of certain flavours is found to exist.

the tongue. Such an opportunity was desirable, because of certain inferences drawn from disturbances of taste observed occasionally in cases of hemi-facial paralysis, which would attribute gustatory power to the facialis. It was of considerable interest, likewise, in connexion with the much-debated question of the physiological function of the chorda tympani; which I reserve for discussion to another occasion.

Now, the result of the paralysis of the inferior maxillary nerve, and consequently of its lingual branch, was that the right anterior two-thirds of the tongue were distinctly less sensitive to touch and taste than the left. Yet as there was complete facialis paralysis on the left side, and as the lesion was not only intra-cranial but intra-pontine, there is every probability that whatever fibres the facialis gives to the chorda tympani were paralysed. It appears to follow from this, that whatever connexion the latter nerve may have with the sense of taste is not attributable to any filaments it may receive from the facialis. This goes to support the conclusion of Professor Schiff, who holds that the chorda tympani represents loan-fibres which had been previously borrowed by the facialis from the trigeminus.

Another question is suggested here, namely, the relationships of the lingual and chorda tympani, respectively, to the senses of touch, pain, and taste. Lussana and Inzani, in 1869, report a case where, after section of the chorda tympani, in the middle ear, the anterior two-thirds of the tongue lost their sensibility to sapid impressions, whilst still sensitive to touch and pain. A complementary fact is found in the result of an experiment by Professor Schiff, who, on dividing the lingual nerve above its junction with the chorda tympani, observed that the anterior two-thirds of the corresponding side of the tongue became insensible to touch and pain, whilst some sensibility to taste-impressions were preserved.

In the case to which I have referred, there was impairment alike of sensibility to touch and to taste. An incident occurred which served to explain the reason of this double impairment, and to furnish a revelation of physiological mechanism of great interest. Owing to a certain want of care on his part, the patient got an attack of tonsillitis; and as a consequence his tongue became "loaded," covered with white fur. In due time, the disorder gave way to treatment, and then a phenomenon was remarked which I will state in the words of a note made at the period:—

"Nov. 24. Tongue completely loaded, white all over.

"Nov. 25. This morning, tongue presented nearly the same appearance. During the course of the day, the left half became clean and red, whilst the right (trigeminal-paralysed) half remained loaded. The right half was quite loaded from tip to back, when I saw him in the evening, whilst the left half was quite clean.

"Nov. 26. Tongue has cleaned still more, but the cleaning has gone on, from left to right,—about a quarter of an inch has now

cleaned off to right of mesial line. This may be due to some intermingling of twigs of left trigeminus with twigs of right. Both being present, there would not be so much recuperative power there as on the left side, where only (the healthy) one present; yet more than on the right side, where the only one present was paralysed."

The whiteness of the right half, comparing so strangely with the redness of the left, continued for two or three days longer before the tongue became completely clean.

From these facts, it is imperative to conclude that the cleaning of the tongue depends directly on the activity of the lingual branch of the trigeminus. Where this activity was diminished, the region supplied by the nerve remained loaded for a considerable time beyond the period of the removal of the fur from the adjoining region, in which the action of the nerve continued. This is a distinct revelation of the trophic influence possessed by this trigeminal branch over the mucous membrane, and papillæ, to which its filaments are distributed. We may infer from what precedes, that the pathological phenomenon of furred tongue is due, at least in a great measure, to temporary paresis of the lingual nerve. The fact that, in some cases, the fungiform papillæ stand out as red points over the white surface does not contradict this opinion, but rather yields it support, inasmuch as their nerve supply being greater than that given to the filiform papillæ, they would thus give way later. Conversely, it may be deduced from the preceding facts, that where the tongue is abnormally red there is unusual excitation of the nerve in question.

Obviously, impairment of taste and touch is a necessary result of the arrest of normal trophic change over the surface of the tongue. When desquamation does not take place, or takes place but slowly, the epithelial scales which remain interpose an obstacle to the due conveyance of impressions; and, whilst remaining, they may undergo morbid change. The loaded tongue cannot perceive sapid impressions well, and we have reason to presume a certain amount, or as it were a film, of effete matter unremoved on the surface of the tongue, whenever there is paresis of the lingual nerve. Hence, we should be on our guard against considering (as some have done) that the impairment of taste which follows paralysis of this nerve is an absolute demonstration of its gustatory power.

An objection to my statement concerning nerve-influence in connexion with the production of fur may, perhaps, be supposed to exist in the opinion that the fur which appears on the tongue is formed by external parasites. Some words on this subject are consequently necessary. Whilst regarding this morbid phenomenon as due mainly to the presence of altered or moulting epithelial cells, it is not, of course, denied that minute plants may be found within the buccal cavity. This has long been known; and it may be added that they appear not only on the tongue, but on the gums, and elsewhere, and have not been regarded as essential to the formation of the fur, of which Rindfleish, the distinguished histologist, remarks:—"What is

called 'fur on the tongue' is merely the result of a considerable desquamation of the epithelial pavement cells which characterise the mucous membrane of that region."

A different view, however, has been proposed by Mr. Bultin, F. R. C. S., in a paper recently read before the Royal Society of London,[3]—the object of his essay being, as he states it, "to show that schizomycetes form the essential constituent of the fur, and to show as far as possible some of the laws which govern the formation of the fur." His theory may be thus summarised: "The tongue," he says, "is kept clean by free movement, and by being rubbed against the interior of the mouth, gums, and teeth; but fur almost always exists on the surface both in health and in disease. The fur is generally thickest in the morning before food is taken, and during illness, when the necessary cleansing is not properly performed." Observed under a microscope the scrapings of a furred tongue show: "1°. debris of food, and bubbles of mucus, and saliva; 2°. epithelium; 3°. masses which appear at first to consist of granular matter, but which are the glœa of certain forms of schizomycetes." These glœa, he observes, are so closely attached to the hair-like processes that these come away with them, and where they are found "the filiform papillæ, instead of exhibiting fine, clear, tapering processes, terminate in processes which are uneven, tuberculated or beaded, and blunted at the ends." This alteration in appearance he considers to be "owing to the presence of these bodies."

With reference to these statements, it may be replied: 1°. that it has not been demonstrated that the deformation of the epithelial processes is not due to pathological alteration, rather than to parasitic growth. Such an alteration would be represented by what my distinguished master, Professor Ranvier, has termed "la tuméfaction trouble des cellules." This turbid cell-tumefaction takes place under like conditions. Whenever a slight irritation exists, or an abnormal variation of the nutritive fluid occurs in the epithelial tissues, "the epithelial cells swell and become filled with an albuminous fluid, containing fine granulations." This, in my opinion, would be the immediate cause of the alterations of the epithelial cells in case of furred tongue. On a mucous surface, so altered, it is quite conceivable that parasitic growth should soon form, because the "vital" resistant power of the tissue must be considerably lessened. It may be added, that if the formation of fur were due, essentially, to the proliferation of parasites, it would be very difficult to understand its occasionally rapid disappearance, either without remedies, or on the exhibition of medicines which are not known to be parasiticidal, and are not applied to the tongue. It would be impossible to account for the cleaning of one half the tongue, whilst the other half remained loaded, in the case quoted, if we take the view of Mr. Bultin as correct.

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[3] "On the Nature of Fur on the Tongue," by Henry Trentham Bultin, F.R.C.S.—*Proceedings of the Royal Society*, No. 195, 1879.

In the second place, I do not believe we can accept the purely mechanical view of the cleaning of the tongue which Mr. Bultin has embodied in these words: "The tongue is kept clean by free movement, and by being rubbed against the interior of the mouth, gums, and teeth . . . the fur is generally thickest in the morning, and during illness, when the necessary cleansing is not properly performed." It is scarcely necessary to remark that the state of the tongue varies much in disease, and that even in the course of one affection, *e. g.*, typhoid fever, it may alter considerably in appearance. Again, in some disorders, when there is no reason to suppose the tongue unduly active, it becomes, so to speak, abnormally clean and red.

If the proposition laid down were correct, then we should expect to see the tongue furred in proportion to its inactivity. This, however, is not so. In the case of Mr. L——, that side of the tongue from which the fur first cleaned off was precisely the side which was paralysed as regards movement, and owing to the facialis paralysis, the cheek had fallen away, flaccid, and did not press the food into the cavity of the mouth, and towards the tongue, as was normally done on the right side, where the fur, in spite of all friction, remained persistently. Again, in cases where the tongue is more or less completely deprived of the power of motion, by paralysis or atrophy, it should, if this theory held good, be thickly coated with fur. But the fact is that the active tongue of (say) a scarlatina patient will be heavily loaded, whilst the motionless tongue of a paralytic may be free, or at least present no abnormal appearance. In labio-glosso-laryngeal paralysis the tongue remains, at a certain stage, motionless, and yet, as I can testify, it is not necessarily loaded. In this disease, first described by my regretted master, Dr. Duchenne (de Boulogne) the debility of the tongue is accompanied by an accumulation of viscous saliva, as he observes, but he distinctly points out that, "nevertheless, neither redness nor any alteration whatever of the buccal or pharyngeal mucous membrane is to be remarked."[4] Professor Charcot, in his great work on Diseases of the Nervous System, describing a case of glosso-laryngeal paralysis,[5] mentions that the patient could no longer make herself understood, the only sound she could produce being a nasal grunt: she could, indeed, protrude her tongue, and move it from side to side, but she could neither turn up the tip, nor apply its dorsal surface to the palate,—thus she could not rub it. Nevertheless, the tongue appeared quite normal. It is useless to multiply instances: enough has been said to prove that the production or removal of fur does not depend, to any marked extent, on the less or greater power of motion possessed by the tongue.

I have already indicated that, when the nerve-action is enfeebled or paralysed, the vitality (so to speak) of the corresponding region is lowered, and the tissue then becomes less able to resist the activity of

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[4] Duchenne de Boulogne, *De l'Electrisation localisée*, p. 568: Paris, 1872.
[5] Charcot, *Leçons sur les Maladies du Système Nerveux*, p. 426: Paris, 1877.

external agents, amongst which we may enumerate parasites. This statement may be illustrated by the facts of another case, which was noted down in 1864, and was made the subject of a Paper by the late Professor Gubler. In this case, the symptoms of which, unfortunately, were not given with much minuteness, we find the existence of anæsthesia of the trigeminus mentioned, as supervening upon another disorder. Sensibility, consequently, was impaired over the left side of the face. The patient having complained of dryness of the mouth, and disagreeable sensations there, attention was directed to the state of the buccal cavity. On examination it was ascertained that the gums and inner side of the cheek on the left side were distinctly drier than the corresponding parts on the right. In addition, a very striking phenomenon was observed. On the left, that is, the anæsthetic side, white granular patches were found disseminated over the posterior gums, the genial mucous membrane, and the angle of the upper and lower maxillæ. Nothing of the kind was to be discovered on the right side. On microscopic examination of scrapings of the white patches, epithelial cells, spores, and numerous long filaments of *Oïdium albicans* were found.[6]

This case supplies an interesting and instructive corroboration of certain conclusions drawn from the facts which came under my personal observation, and gives us some additional data for judging the mechanical cleansing theory. Here were two regions perfectly identical as regards their motor conditions, as well as with respect to whatever friction they might experience. From one region, however, the influence of the trigeminus was more or less completely withdrawn, owing to its paralysis, and, in this region, parasitical growths were found to develop on the surface membrane, whilst no such phenomena were discoverable in the region where trigeminal action remained intact.

From what precedes, it is necessary to conclude:—

1°. That the action of the trigeminus influences, in a marked manner, the nutrition of the epithelial cells of the tongue and other parts to which its filaments are distributed.

2°. That diminution of its action is followed by diminution of the desquamation process.

3°. That, owing to this arrest of elimination of effete cells, the senses of Touch and Taste become impaired.

4°. Diminished action of the trigeminus results in diminished power of resistance, on the part of the corresponding surface membrane, to the action of pathological alteration in its anatomical elements and to the invasion of external agents, such as parasitical growths.

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[6] Professor Gubler's attention having been confined to the phenomenon of dryness, he failed to discern the real cause at work. He, in fact, candidly records his failure.

XLIV.—Contributions to the Study of Nerve Action in connexion with the Sense of Taste. II.—Functions of the Chorda Tympani.

By George Sigerson, M.D., Ch. M., F.L.S.

[Read, February 9, 1880.]

In the preceding Paper certain facts have been demonstrated with respect to the functions of nerves supplying the tongue and buccal cavity. From these facts the following conclusions, amongst others, may be deduced:—

The so-called gustatory nerve is not exclusively, if at all, a nerve of taste. It exercises, as I have proved, a remarkable influence over the epithelial cells of the tongue. When its action is annulled by paralysis, there is retardation or arrest in the elimination of these cells. Hence the conditions necessary for the proper performance of the function of taste are disturbed; a film of effete matter, which, in other circumstances, would have been shed off, now remains, and interposes between the sapid substance and the taste organ. In this manner, the acuteness of the sense of taste might become dulled or diminished to a considerable extent, after paralysis of the "gustatory" nerve, without that diminution going to prove that this nerve is in truth a nerve of taste. Even if we supposed it to be merely a trophic nerve (which I by no means affirm), there would necessarily be some loss of taste, if paralysis prevented the accomplishment of its trophic work.

The continuance of the power of tasting in the anterior portion of the tongue after paralysis, and even after section of the gustatory or lingual nerve, compels us to regard the chorda tympani as the principal nerve of taste in this region. The question of its action is involved in considerable obscurity, and it can scarcely be said that its constitution has yet been definitely demonstrated. Bérard declared that the chorda tympani was an enigma propounded to the sagacity of physiologists. Recently Béclard has pointed out that, "whilst many suppositions have been made concerning the rôle of this singular nerve, it must be confessed that more than one obscurity remains to be cleared up in connexion with it."[1]

Again, whilst some physiologists consider that it obtains its taste-filaments from the facialis (thus making the latter to be a nerve of taste), others maintain that the fibres so obtained were previously borrowed by the facialis from the glosso-pharyngeus or the trigeminus. Against the first-mentioned opinion I adduced the fact that, in a case of absolute facialis-paralysis of one side, arising from pontine

[1] Béclard, *Traité de Physiologie*. Paris, 6e édition, p. 1016.

lesion, taste was not abolished, nor noticeably diminished in the corresponding region of the tongue, as would have necessarily happened if the facialis had furnished taste-filaments.

Bellingeri was, it would seem, the first to attribute an active rôle, in the function of taste, to the chorda tympani. His opinion has been confirmed by the experiments of Moos, who has pointed out that, in cases in which compression of the chorda tympani was caused by certain operations in the ear, transient loss of taste supervened. In the case of a patient from whom one half of the inferior maxilla had been removed, together with the chorda tympani and the facialis at its exit from the stylo-mastoid foramen, the gustatory nerve being preserved, the sense of touch persisted on the corresponding anterior region of the tongue, but the sense of taste had disappeared. This experiment, however, did not differentiate the function of the chorda tympani from that of the facialis. When the chorda tympani is divided, in animals, it is found that the sense of taste is obscured, whilst the sense of touch remains.

The abstraction of a factor, though it may suffice to solve some problems, is not capable of supplying satisfactory answers to the complex questions which we have to deal with in this instance. In order to understand the properties of the nerve in question with some degree of completeness, it is not enough to observe what takes place when its action is annulled, by whatever cause; we must also endeavour to distinguish what phenomena happen when the nerve is stimulated to action. Now, this experiment may be performed on animals; but as animals cannot intelligibly express the gradations of perception obtained through a special sense-organ, the result must of necessity be unsatisfactory—more especially as it yet remains to be shown that their perceptions of sapid impressions are in perfect unison with those of man. Hence, with respect to the case in point, it is requisite to experiment on man.

The agent of excitation which I found most useful was volta-faradaic electricity, following, in this respect, the example of my late distinguished master, Dr. Duchenne (de Boulogne). Having, therefore, employed faradisation in such a manner as to stimulate the chorda tympani, on at least two hundred occasions, I may, I trust, consider that the opportunities of observation have been sufficiently frequent to reduce the risk of error to a minimum. One of the rheophores was placed, immersed in water, in the external meatus; the other was usually applied in the immediate vicinity. The time occupied by each experiment varied from five to twenty minutes; the action of both currents was tested separately; the number of interruptions was varied, and different degrees of intensity, from the feeblest to the strongest that could be borne, were employed.

Finally, in order to clear up some points, and to determine more accurately, if possible, the several phenomena produced, I considered it necessary to personally undergo the experimentation.

The results of these various experiments may be summarised as

follows: Some of them, I may mention, are confirmatory of those mentioned by Dr. Duchenne (de Boulogne), whilst others are additional, and pertain solely to my own observation.

The functions of the chorda tympani, then, as far as can be determined by the results of faradaic stimulation of that nerve on its passage in the ear, may be described as follows:—

1°. The sensation of a peculiar taste is produced, which can only be described as "metallic," to use the term employed by Dr. Duchenne. This taste is not always perceived immediately on excitation of the nerve; occasionally, repeated stimulation is necessary before this sensation is experienced. Some persons, on the contrary, notice it early and constantly, even with a moderate intensity of excitation. Thus different degrees of stimulation are required to cause its production in different individuals.

2°. A sensation of astringency is occasionally experienced. This has been perceived several times by persons on whom I have experimented. When experimenting on myself I observed the same sensation, and recognised that it was due to a peculiar thrill caused by the stimulated nerve.

This fact has not hitherto been described.

3°. A sensation of dryness and roughness over the corresponding region of the tongue is frequently noticed. Here I have to confirm the observation of Dr. Duchenne, with this addition, that I believe we may attribute the production of this roughness on the tongue to the same mechanism which, on similar stimulation, produce roughness on the cutaneous surface (commonly known as "goose-skin"). I found that the power of setting this mechanism at work was lost to a surface-region affected by paralysis of the ulnar nerve. Here, especially in the outer portion of the hand, the skin was smooth and somewhat parchment-like.

4°. A sensation of prickling and numbness, as where a nerve of general sensibility is excited, is a usual consequence of the stimulation. Dr. Duchenne has remarked it. In my experience I have observed that this sensation, although generally affecting the anterior two-thirds of the tongue on the same side with the operation, may, nevertheless, vary in extent and position within certain limits. Sometimes, for instance, but a small area may be first affected, and a gradual enlargement of area may go on until the entire of the corresponding region be included. In most cases, this may require only a few minutes; but, in some, repeated stimulations may be necessary. In one case I observed that, whilst on one side the anterior two-thirds were affected by this sensation, on the other only a circumscribed region (say, the middle third on that side) was affected: the area increased, under the influence of repeated stimulations, but never quite advanced to the tip of the tongue. Lastly, in another instance, the result of the stimulation was invariably to produce, amongst other things, a tickling irritation in the throat, which was followed by a short dry cough.

Can we explain the diversities of effect described by supposing a

certain diversity in the distribution of the terminal nerve-filaments?

5°. Stimulation of the chorda tympani, when sufficiently strong, causes a flow of saliva into the buccal cavity from the sub-maxillary glands. This phenomena is in conformity with the discovery of Claude Bernard, that section of the chorda determines cessation of secretion in this gland—a discovery which demonstrated the existence of a filament of communication with the sub-maxillary gland, which Cruveilhier had disputed. Dr. Duchenne (de Boulogne) has stated that he did not notice this salivation until his attention had been called to Claude Bernard's experiment, and even then but rarely. For myself, I have frequently observed the occurrence of this phenomenon (which is not, however, constant). This was due, in part, I have no doubt, to the fact that I found it possible to use more stimulant power than he was in the habit of employing.

6°. Finally, I have ascertained that excitation of the chorda tympani is occasionally represented by motion in the region of the tongue supplied by the nerve operated on. Care was, of course, taken to exclude all sources of error from involuntary movements of the tongue. This phenomenon was not discovered by Dr. Duchenne (de Boulogne), owing, doubtless, to the slight intensity of the current he employed in such cases; nor has it been noticed in experiments on animals. However, after having carefully studied the production of slight tremulation in the case of others (and sometimes a certain alteration of shape in the tongue), under the influence of strong stimulation of the nerve in question, I controlled and verified the results by experiments on myself. Consequently, I believe, it may be accepted as a fact, that stimulation of the chorda tympani causes not only sensations of taste, astringency, dryness, roughness, prickling, to be produced, as likewise salivation, but that it also causes the production of a certain feeble motion—in other words, that it is not only a nerve of special and general sensibility, and of secretion, but also that it possesses some few feeble motor filaments, which may, in fact, be derived from the facialis, from which it obtains no taste-filaments.

XLV.—The Application of Spectrum Analysis to the estimation of Bile in the Renal Secretion of Patients suffering from Jaundice. By F. J. B. Quinlan, M.D., Univ. Dubl., Fellow of the King and Queen's College of Physicians, and Physician to St. Vincent's Hospital.

[Read, January 26, 1880.]

For some time past efforts have been made by physicians and physiologists to introduce into their respective branches tests and measures of precision, in lieu of the vague and approximate observations of the unaided senses; and this movement has led to excellent results. The action of the heart is now recorded graphically by the sphygmograph; respiration is similarly delineated; the rapidity of the circulation is exactly measured; and albumen or diabetic sugar (existing as abnormal constituents of the urine) are expeditiously and accurately estimated by the Jellett saccharimeter—which is by far the best of this class of instruments. I am permitted by the kindness of your Council to submit to your consideration what appears to me to be a contribution to this movement in the form of a simple and effectual test for detecting the presence of bile (or, at least, its colouring matter) in the urine of patients suffering from jaundice; and of approximately estimating its increase or decrease (according as the patient gets better or worse) in the same individual. I say "approximately in the same individual," for the bile is not a secretion of definite strength. About two[1] pounds of it are secreted daily in an ordinary healthy person; but its quality varies, not only in different persons, but in the same person at different times. For this reason we cannot establish an absolutely quantitative formula; but we are certainly able to watch the increase or decrease of the colouring matter in the urine of the same jaundiced patient. The qualitative tests at present most employed in medical practice are those of Gmelin and of Pettenkoffer; but neither are perfectly reliable. In Gmelin's test a drop of nitric acid is let fall on a thin layer of the suspected urine, which has been allowed to flow upon a white plate; and if bile be present an iridescence is produced, beginning with green, and running into blue, violet, red, and yellow; but this will also occur in the presence of the indigo[2] forming matter occasionally found in the urine as a concomitant of carcinomatous disease and diseases of mal-nutrition. In Pettenkoffer's method a peculiar violet brown colour is developed by the action of sulphuric acid and cane sugar upon urine containing bile; but even here there are sources of error in connexion with the presence of albumen, turpentine, or

[1] Burdon Saunderson, 1879.

[2] This used to be supposed to be identical with the vegetable indigo principle *Indican;* but Hoppe Seyler has shown that it is rather different. It is derived from Indol [C_8H_7N], and its formula is $C_8H_6N\,SO_4\,K$. The defect in Gmelin's test has been described by Carter, and more recently by W. G. Smith.

certain essential oils. It will thus be seen that a simple and reliable test of the colouring matter of bile is a desideratum; and the one I propose is founded on the fact that this colouring matter possesses a power of selective absorption of the solar spectrum, commencing with the violet, and extending (according to the quantity present) nearly as far as Frauenhofer line D. Further, that this colouring matter does not produce any absorptive bands, nor interfere with the red end of the spectrum. After many trials I found that this test is best employed by placing in front of the slit a stratum of fluid of *3mm.* in thickness; a thinner one has not sufficient absorptive power, and a thicker is not so delicate—a very deep stratum (even though the solution be weak as regards bile) produces a coarse obscuration not suitable for the test. So many skilled observers are now employed in every branch of medical research, especially in Germany, that it is not impossible that this test may have been already described by somebody else. I do not, however, see any mention of it in Neubauer and Vogel on the Urine, or in Frerichs on the Liver; and the exhaustive and admirable work on Physical Diagnosis of Guttmann of Berlin, just issued by the Sydenham Society, is equally silent. I first observed it some years ago when examining jaundiced urine with a small spectroscope, exhibiting two conterminous and independent spectra lighted from different sources; and I found the test so useful for clinical teaching purposes, that I procured a larger instrument specially adapted for its development. In fact, with a Jellett saccharimeter and this instrument a clinical teacher is able to test most delicately for albumen, diabetic sugar or bile, and to estimate the two former exactly, and the latter approximately—and all this with much less trouble and less loss of time than in the ordinary coarse clinical procedures. Returning to the bile test, I wish to mention that it is not my intention on the present occasion to discuss its medical value—a subject more congenial to a purely medical society. For the present I will assume that it is important to the physician to be able to detect bile in the urine in jaundiced patients, and to watch its increase or decrease; and, having made this assumption, will describe the details of the test, and respectfully invite the opinion of this eminent scientific body on its strictly scientific aspect. The instrument is a single prism one, the telescope of which is furnished with a fine needle[1] in the eye-piece, and revolves (with a coarse and fine adjustment) on a segment of the ordinary degree circle—the collimating tube having before the slit a means of holding a thin, flat glass test-tube of *2mm.* in thickness. Minutes as well as degrees can be read off by the aid of an ordinary vernier. I place this instrument on my laboratory bench, in front of a window, in such a manner that, while the needle is resting on some definite Frauenhofer line, as far back in the violet as possible, the zero of the vernier may point exactly to some degree. In the present instance

[2] This needle was first suggested by Professor O'Reilly, M.R.I.A., of the College of Science, Dublin; and is, in my opinion, superior to any of the usual means of spectrum measurement.

the degree pitched upon was 51°, and the Frauenhofer a well-known line between F and G, which I designate (little) g. Having now either fixed the instrument permanently to the bench, or else very accurately marked out its position, a permanent working constant is established; for when the instrument is in its exact place, and the zero rests on the selected degree, the observer may be sure (even when working by artificial light) that the needle points to the position corresponding to g. Should the observer be working in a strange place, and without sunlight, there is a bright potassum line on the violet side of g, which will give an equally good constant, and may even be made by a previous observation to determine g. The total range of the spectrum of my testing instrument from g in the violet to B in the red is 3° 38′; of which average human bile absorbs 2° 23′, leaving 1° 15′ (or a small fraction more than one-third) of the spectrum unaffected. In human bile the golden red colouring matter, known as Bilirubin $C_{16}H_{18}N_2O_3$ predominates; but in that of the ox and sheep the green Biliverdin [$C_{16}H_{20}N_2O_5$, or according to Maly $C_{16}H_{18}N_2O_4$] is in the ascendant, sheep bile being the greener of the two. It is therefore interesting to find that the absorptive co-efficients of these biles exhibit corresponding differences—that of the ox absorbing 2° 13′, and that of the sheep 2° 7′, as compared with the 2° 23′ of human bile. I now proceeded to examine the effect of aqueous solutions of bile of gradually increasing strength; and for this purpose, on account of the difficulty of obtaining perfectly fresh human bile in quantity, used fresh ox bile. The weakest solution which produced any perfectly definitive effect on my instrument was 5 per cent.; which was of a very pale straw-colour, and exhibited an absorption of 6′. Submitting solutions of gradually increasing strength and colour, I found that there was an increase of about 8′ for every 5 per cent. of bile up to 75 per cent., when the solution scarcely differed in appearance or opacity from pure bile, and produced an absorption of only 20′ less than that of the pure secretion (2° 13′). The shadow thus produced was of an olive greenish black, greener than that of blood (which I shall presently describe); different from any other shadow that I am acquainted with; and, in my experience, pathognomonic of the colouring matter of bile. And I may add that, in many instances, the daily observations of the increase or decrease of bile colouring matter, so made, has been most useful for diagnostic purposes. The cardinal point, however, connected with this test is, that bile, from its weakest solution up to absolute purity, does not exhibit any separate absorptive bands or touch the red end of the spectrum; and the importance of this point I will presently explain.

To establish the value of the test, however, it is essential to inquire whether any of the normal or abnormal constituents of the urine, except bile, possesses this special absorptive power. I have searched long and carefully into this question, but with a negative result. Commencing with the colloids, albumen has no effect upon the spectrum, nor have pus or mucus. Blood is frequently found, as a

haemorrhagic product, in the urine; and its spectrum requires attention and comparison. Arterial blood, in the thin layer of solution, absorbs a small portion of the violet end, and venous blood still more; but in arterial blood we find the two well-known oxyhaemoglobin absorptive lines between D and E, and in venous blood the equally well-known single dark absorption line of reduced haemoglobin nearer the red. Blood, moreover, has a very slight but distinct absorptive power in the red end. Bile, as I have mentioned before, only absorbs the violet end, has no separate absorption lines, and does not in the least affect the red. The microscopical and chemical detection of blood is easy; but, even with the spectroscope alone, there is no difficulty in this differentiation; and I have again and again detected the blood lines (either arterial or venous) in instances where blood became accidentally mixed with the bile in the process of removal. The bile absorption (in solutions of equal strength) overlaps the blood (violet) absorption; and there is no difficulty in detecting both blood and bile in the same specimen; for accuracy, however, pure solutions of either are preferable. Diabetic sugar or the crystalloids have no effect whatever on the solar spectrum.

It is now believed by physiologists that the source of the colouring matter of the bile is the disintegration of the red corpuscles which takes place in the spleen. This belief is principally founded on the fact that the injection of haemoglobin into the blood-vessels of a living animal causes a great effusion of bile colouring matter into the urine, and increases the quantity of Bilirubin in the bile. It appears to me that the fact of haemoglobin, in addition to its characteristic absorptive bands, absorbing the violet end of the spectrum like bile, is confirmatory of the present physiological view as to the nature of bile colouring matter.

Nothing could be more unlike the yolk of an egg, rich in proteids, than the bile, which contains none; and yet it has always appeared to me that there was a certain similarity between the golden-coloured bile and the golden yellow colouring matter of the yolk; and I have long thought both were derived from disintegrated haemoglobin. On applying my test to the yolk, emulsified with three times its own quantity of water, I find it has an absorption nearly identical with that of bile. The yolk, so treated, absorbs 2° 5′ of the violet end of the spectrum, and without absorption bands. Here we have an interesting chain of reasoning. We cannot synthetically make Bilirubin, but we can do so indirectly by injecting haemoglobin into the blood of a living animal, and thus produce a haemoglobin derivative, which will absorb the violet. Does it not seem possible that the colouring matter of the yolk is a similar haemoglobin derivative?

I make this suggestion, however, in a purely tentative spirit, and without in the least expressing an opinion as to its accuracy or otherwise. In this communication I wish to confine myself strictly to my bile test. The conclusions which appear derivable from it are as follow:—

1. That an easy and reliable qualitative test of the presence of the colouring matter of bile in the urine is afforded by placing a 3*mm.* stratum of the suspected fluid before the slit of the spectroscope, and observing whether the special absorption, which I have described, takes place.

2. That no other normal or abnormal constituent of the urine affords this special absorption.

3. That to so examine such suspected urine, by the bedside of the patient, with one of the small but effectual spectroscopes, which are now so constructed as to be easily carried in the waistcoat pocket, is a procedure as quick and easy as Gmelin's test, and quicker and easier than Pettenkoffer's. I believe it to be more reliable than either.

4. That the daily increase or decrease of the absorption (in the same individual) is capable of approximately indicating the increase or decrease of the biliary colouring matter in the urine; and, *pro tanto*, the extent of the excretion of bile through that channel.

5. That this test affords an additional proof of the present physiological opinion, that biliary colouring matter is a haemoglobin disintegration derivative.

Demonstrations of the various spectra described were given.

NOTE ADDED IN THE PRESS.

Since the reading of this Paper Dr. Charles A. MacMunn's new work, "The Spectroscope in Medicine," has come to hand. This volume abounds in original research, and contains information of the most valuable and practical kind; it does not, however, describe this particular test for bile.

At the suggestion of Dr. G. Sigerson, M.R.I.A., the author has tried whether the acidity or alkalinity of the icteric urine altered its peculiar absorptive power; and he finds that it does not.

XLVI.—EXPERIMENTS MADE TO DETERMINE THE "DRAG"[1] OF AIR UPON AIR AND OF WATER UPON WATER AT LOW VELOCITIES.

By the REV. SAMUEL HAUGHTON, M.D., D.C.L., and J. EMERSON REYNOLDS, M.D.

[Read, February 23, 1880.]

A SPHERICAL ball of granite, unpolished, was suspended by a pianoforte wire, and allowed to hang freely; from the brass collar by which the ball was suspended an index projected on each side, the pointed ends of the indices traversing a graduated horizontal circle, whose centre corresponded with the line of suspension. The suspended ball was immersed in water contained in an iron tub.

The weight of the granite ball was 22452·85 grams, and its mean diameter was 251·46 millimeters. The length of the wire of suspension was 610·8 centimeters, and its diameter was 0·889 millimeter. The diameter of the iron tub was 2 ft. 4 in., and the depth of water contained in it was 1 ft. 9 in.

The method of observation was as follows: the indices of the ball having arrived at the zero of rest, the ball was then displaced by a torsional movement of the wire, and allowed to regain its position of rest by a succession of vibrations of diminishing amplitudes.

The quantities observed were, the time of vibration and the rate of diminution of the amplitude.

The equations of motion of the apparatus are thus found:—

$$\frac{d^2x}{dt^2} - X = 0; \qquad (1)$$

where x = the varying amplitude of any point of the surface of the ball measured from the zero of rest;

X = the tangential forces of torsion and "drag" acting at the point x.

If we assume that for low velocities the friction will be proportional to the velocity, we shall have

$$X = k^2x - f\frac{dx}{dt}; \qquad (2)$$

where k is a coefficient depending on torsion, and f is a coefficient depending on "drag."

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[1] By the term "Drag," I understand the combined effects of Friction and Viscocity.

It is easy to see that the complete integral of the equation of motion,

$$\frac{d^2x}{dt^2} + f\frac{dx}{dt} + k^2x = 0, \tag{3}$$

must be of the form

$$x = ae^{mt}\cos nt + be^{mt}\sin nt, \tag{4}$$

where a and b are arbitrary constants, and where m and n have the values

$$m = -\frac{f}{2};$$
$$n = \sqrt{k^2 - \frac{f^2}{4}}. \tag{5}$$

If we reckon the time from the commencement of the oscillation, equation (4) reduces to

$$x = ae^{mt}\cos nt. \tag{6}$$

If T denote the time of a complete double oscillation, we find from the above

$$\theta_n = \theta_o e^{-\frac{fnT}{2}} \tag{7}$$

where

θ_n = amplitude of the $(n+1)^{th}$ vibration;
θ_o = amplitude of the first vibration.

From (7) we obtain the following working equation, for use in the calculations to determine the coefficient of friction :—

$$f = \frac{2}{nT}\log_e\left(\frac{\theta_o}{\theta_n}\right). \tag{8}$$

Also, we have,

$$n = \frac{2\pi}{T} = \sqrt{k^2 - \frac{f^2}{4}};$$

from which we obtain, after some reductions,

$$T = \frac{4\pi}{\sqrt{4k^2 - f^2}}. \tag{9}$$

If we introduce into this equation the value of f determined by (8), we obtain k, which depends on the torsion only.

T = 1·51 MINUTE.

Details of Experiments on Air.

1. 28*th May*, 1879 :—

Hour.	n = vibrations, number of complete.	θ = amplitude of whole arc.
9 A.M.	00°·0	130°·0
10 ,,	39 ·8	99 ·0
11 ,,	79 ·5	68 ·0
Noon,	119 ·2	56 ·5
1 P.M.	159 ·0	43 ·5

From these data I find—

First hour, ... $f = 1 \div 6626$
Two hours, ... ,, 5564
Three ,, ... ,, 6487
Four ,, ... ,, 6590

Mean of all, ... $f = \frac{1}{6317}$.

2. 30*th May*, 1879 :—

Hour.	n	θ
0	00°·0	92°·00
1	39 ·8	68 ·70
2	79 ·5	50 ·20
3	119 ·2	38 ·90
4	159 ·0	30 ·50
5	198 ·7	22 ·00
6	238 ·4	16 ·85
7	278 ·2	12 ·75

From these data I find—

One hour, ... $f = 1 \div 6191$
Two hours, ... ,, 5952
Three ,, ... ,, 6278
Four ,, ... ,, 6532
Five ,, ... ,, 6299
Six ,, ... ,, 6735
Seven ,, ... ,, 6384

Mean of all, ... $f = \frac{1}{6339}$.

3. 31*st May*, 1879 :—

Hour.	n	θ
0	00°·0	92°·75
1	39 ·8	68 ·25
2	79 ·5	49 ·50
3	119 ·2	37 ·50
4	159 ·0	26 ·75
5	198 ·7	21 ·00

From these data I find—

One hour, ... $f = 1 \div 5885$
Two hours, ... ,, 5742
Three ,, ... ,, 5970
Four ,, ... ,, 5799
Five ,, ... ,, 6067

Mean of all, ... $f = \frac{1}{5893}$.

4. 13*th June*, 1879 :—

Hour.	n	θ
0	00°·0	100°·00
1	39 ·8	71 ·75
2	79 ·5	54 ·50
3	119 ·2	39 ·40
4	159 ·0	31 ·25

From these data I find—

One hour, ... $f = 1 \div 5437$
Two hours, ... ,, 5940
Three ,, ... ,, 5804
Four ,, ... ,, 6200

Mean of all, ... $f = \frac{1}{5845}$.

5. 14*th June*, 1879 :—

Hour.	n	θ
h. m.		
0·00	00°·0	100°·00
1·00	39 ·8	74 ·25
2·30	99 ·3	47 ·25
3·30	139 ·0	35 ·50
4·30	179 ·0	26 ·00

From these data I find—

One hour, ... $f = 1 \div 6062$
Two and a-half hours, ... ,, 6007
Three ,, ,, ... ,, 6087
Four ,, ,, ... ,, 6027

Mean of all, ... $f = \frac{1}{6046}$.

6. 16*th June*, 1879 :—

Hour.	n	θ
h. m.		
0·00	00°·0	100°·00
1·00	39 ·8	73 ·75
2·00	79 ·5	55 ·00
3·00	119 ·2	39 ·00
4·00	159 ·0	29 ·00
4·30	179 ·0	25 ·00

From these data I find—

One hour, ... $f = 1 \div 5928$
Two hours, ... ,, 6031
Three ,, ... ,, 5741
Four ,, ... ,, 5826
Four and a-half hours, ... ,, 5856

Mean of all, ... $f = \frac{1}{5876}$.

I have no doubt, from the close agreement of the results of each day's experiments, that the differences observed from day to day are real, and depend upon the varying temperature and pressure of the atmosphere : but, as my present object is only to find a general mean

value for the "drag" of air upon air, I shall take the average of all six days, which give us—

$$\frac{1}{f}:$$

1.	28th May, 1879, ...	6317
2.	30th ,, ,, ...	6339
3.	31st ,, ,, ...	5893
4.	13th June, ,, ...	5845
5.	14th ,, ,, ...	6046
6.	16th ,, ,, ...	5876

Mean of all, ... $f = \frac{1}{6052{\cdot}7}$.

T = 1·56 MINUTE.[1]

Details of Experiments on Vartry Water.

1. *3rd July*, 1879.—Observed by Dr. Reynolds, using single readings of one index :—

n	θ	Combination.	$\frac{1}{f}$
0	110°·00		
1	95 ·00		
2	81 ·00		
3	69 ·00		
4	58 ·50		
5	50 ·50		
6	42 ·50	(0, 6)	$\frac{1}{295{\cdot}6}$
7	36 ·50		
8	31 ·00		
9	26 ·25		
10	22 ·50		
11	19 ·00		
12	16 ·00	(0, 12)	$\frac{1}{291{\cdot}6}$
Mean, ... $f = \frac{1}{293{\cdot}6}$.			

[1] Some alterations (of a slight kind) had been made in the mode of suspension of the ball, after the trials in air.

2. *2nd July,* 1879.—Observed by Dr. Reynolds, using single readings of one index :—

n	θ	Combination.	$\frac{1}{f}$
0	98°·00		
1	85 ·00		
2	72 ·50		
3	62 ·50		
4	53 ·50		
5	46 ·00	(0, 5)	$\frac{1}{309\cdot7}$
6	40 ·00		
7	34 ·00		
8	29 ·00		
9	25 ·25		
10	21 ·25	(0, 10)	$\frac{1}{306\cdot5}$
11	18 ·00		
12	16 ·00		
13	13 ·00		
14	11 ·50		
15	10 ·60	(0, 15)	$\frac{1}{307\cdot9}$
16	8 ·00		

Mean, ... $f = \frac{1}{308\cdot03}$.

3. *7th July*, 1879.—Observed by Dr. Macalister and self, using single readings of one index :—

n	θ	Combination.	$\frac{1}{f}$
0	101°·25		
1	87 ·50		
2	75 ·50		
3	65 ·00		
4	55 ·00		
5	48 ·75		
6	41 ·25	(0, 6)	$\frac{1}{313\cdot1}$
7	35 ·75		
8	29 ·50		
9	26 ·75		
10	22 ·50		
11	18 ·50		
12	17 ·00		
13	15 ·00	(0, 13)	$\frac{1}{318\cdot9}$
Mean, ... $f = \frac{1}{316\cdot0}$.			

4. *8th July*, 1879.—Observed by Dr. Macalister and self, using double readings with both indices :—

n	θ	Combination.	$\frac{1}{f}$
0	102°·125		
1	87 ·875	(0, 1)	311·7
2	75 ·375	(0, 2)	308·5
3	64 ·750	(0, 3)	308·5
4	56 ·000	(0, 4)	311·9
5	47 ·875	(0, 5)	309·2
6	41 ·625	(0, 6)	313·2
7	35 ·750	(0, 7)	312·5
8	30 ·750	(0, 8)	312·3
9	26 ·375	(0, 9)	311·5
10	22 ·750	(0, 10)	312·0
Mean, ... **311·13 ± 0·37** (mean probable error).			

The mean of the three observations with single readings is,

$$f = \frac{1}{305{\cdot}88},$$

and the mean of all the observations made with amplitude θ_o, nearly 100°, is

$$f = \frac{1}{308{\cdot}50}.$$ [1]

5. *9th July*, 1879.—Observed by Dr. Macalister and self, using double readings with both indices:—

n	θ	Combination.	$\frac{1}{f}$
0	346°·500	(0, 15)	307·0
1	298 ·000	(0, 1)	310·7
2	253 ·250	(0, 2)	298·9
3	missed	—	—
4	186 ·500	(0, 4)	302·5
5	158 ·670	(0, 5)	299·7
6	136 ·870	(0, 6)	302·3
7	116 ·750	(0, 7)	301·5
8	100 ·620	(8, 13)	306·7
9	86 ·250	(5, 9)	307·4
10	74 ·250	(5, 10)	308·7
11	63 ·750	(5, 11)	308·3
12	54 ·500	(0, 12)	304·0
13	46 ·875	(0, 13)	304·5
14	40 ·375	(10, 14)	307·7
15	35 ·125	(10, 15)	313·0
Mean, . . .	= **305·53** ± **07·1** (mean probable error).		

[1] I counted the fourth observation with double readings, equal in value to the mean of the three observations with single readings.

6. *9th July*, 1879.—Observed by Dr. Macalister and self, using double readings with both indices :—

n	θ	Combination.	$\frac{1}{f}$
0	346°·750	(0, 16)	306·3
1	295 ·875	(0, 15)	306·9
2	254 ·375	(0, 14)	308·5
3	217 ·500	(0, 11)	307·3
4	187 ·625	(0, 4)	305·1
5	160 ·625	(0, 5)	304·4
6	137 ·375	(0, 6)	303·6
7	118 ·500	(0, 7)	305·4
8	102 ·500	(0, 8)	307·5
9	88 ·000	(5, 9)	311·5
10	75 ·750	(5, 10)	311·7
11	64 ·825	(5, 11)	309·8
12	55 ·250	(0, 12)	306·1
13	48 ·125	(0, 13)	308·4
14	41 ·375	(10, 14)	309·9
15	35 ·125	(10, 15)	304·8
16	30 ·000	(10, 16)	304·2
Mean, ...		**307·14** $\pm$ **0·41** (mean probable error).	

The mean of this and the preceding Table is

$$f = \frac{1}{306{\cdot}335}$$

for amplitudes ranging up to 360°. The mean value of f, from all the experiments, is as follows :—

$\frac{1}{f}$:

Mean value of 1, 2, 3, 4, ...	308·50
Mean value of 5, ...	305·53
Mean value of 6, ...	307·14
Mean of all, ...	**307·057**

From the preceding value of f we can determine the relation between the slope of a water-surface and its velocity. We have, for the equation of motion of the surface,

$$\frac{d^2x}{dt^2} = g \sin i - f\frac{dx}{dt}; \qquad (10)$$

where g denotes the force of gravity, i the slope of the surface, and x the distance of any particle from the origin measured in the direction of the motion. If v denote the velocity of a particle, equation (10) becomes at once

$$\frac{dv}{dt} + fv = g \sin i; \tag{11}$$

which gives, by integration,

$$e^{ft}(g \sin i - fv) = \text{const.} \tag{12}$$

This indicates that the velocity will increase from zero up to the value given by

$$g \sin i - fv = 0, \tag{13}$$

after which it will remain constant for ever.

The final constant velocity given by equation (13) is

$$v = \frac{g \sin i}{f} = 32{\cdot}2 \times 307{\cdot}057 \sin i. \tag{14}$$

If we express the velocity in feet per second, and call h the slope per mile, we find

$$v = 1{\cdot}8726 \times h \text{ ft. per second}; \tag{15}$$

which is equivalent to

$$v = 30{\cdot}642\ h \text{ miles per day.} \tag{16}$$

Dr. Carpenter has proposed to explain the phenomena of ocean circulation by the greater height of the water at the equator as compared with that at the poles.

If we call the distance from the equator to the pole 6000 miles, and suppose the velocity of the surface current towards the pole to be only one mile per day, we find from equation (16), that this would require a head of water at the equator

$$h = 195{\cdot}80 \text{ feet.}$$

No such difference of level can be admitted between the equilibrium levels of the equatorial and polar oceans.

The latest accurate estimate of the difference is that made by Mr. Croll, viz., $4\frac{1}{2}$ feet.

This head of water, if it could produce an oceanic flow at all, would be one at the rate of one mile in 42·567 days; or a flow that would occupy 700 years to pass from the equator to the poles.

XLVII.—MATHEMATICAL NOTES. By A. H. ANGLIN.

[Read, January 12, 1880.]

ABSTRACT.

I.

If α_1, α_2, α_3, . . . α_m *be roots of the equation*

$$x^m = p_1 . x^{m-1} + p_2 . x^{m-2} + p_3 . x^{m-3} + \ldots + p_m,$$

then

$$h_n = p_1 . h_{n-1} + p_2 . h_{n-2} + p_3 . h_{n-3} + \ldots + p_m . h_{n-m} \; (n > m),$$

where h_n *is the sum of the homogeneous products of* α_1, α_2, α_3 . . . α_m *of* n *dimensions.*

The proof of this may be briefly indicated thus :—

We have

$$x^m - p_1 . x^{m-1} - p_2 . x^{m-2} - \ldots - p_m = (x - \alpha_1)(x - \alpha_2) \ldots (x - \alpha_m).$$

Writing $\frac{1}{x}$ for x, multiplying off by x^m, and finally equating coefficients of x^n in both members of the equation, we shall find that

$$h_n - p_1 . h_{n-1} - p_2 . h_{n-2} - \ldots - p_m . h_{n-m} = 0;$$

or,

$$h_n = p_1 . h_{n-1} + p_2 . h_{n-2} + p_3 . h_{n-3} + \ldots + p_m . h_{n-m}.$$

The particular case of a quadratic equation is then noticed. If α, β be roots of $x^2 = px + q$, we have

$$h_n = p . h_{n-1} + q . h_{n-2},$$

where h_n is the sum of the homogeneous products of α, β of n dimensions. From this it is deduced that

$$h_{2n} = p^{2n} + (2n-1) . p^{2n-2} . q + \frac{(2n-2)(2n-3)}{1 . 2} . p^{2n-4} . q^2$$

$$+ \frac{(2n-3)(2n-4)(2n-5)}{1 . 2 . 3} . p^{2n-6} . q^3 + \ldots + \frac{(n+1) . n}{1 . 2} . p^2 . q^{n-1} + q^n$$

. . . . . (1)

and that

$$h_{2n+1} = p^{2n+1} + 2n \cdot p^{2n-1} \cdot q + \frac{(2n-1)(2n-2)}{1 \cdot 2} \cdot p^{2n-3} \cdot q^2$$

$$+ \frac{(2n-2)(2n-3)(2n-4)}{1 \cdot 2 \cdot 3} \cdot p^{2n-5} \cdot q^3 + \ldots + \frac{(n+2)(n+1) \cdot n}{1 \cdot 2 \cdot 3} \cdot p^3 \cdot q^{n-1}$$

$$+ (n+1) \cdot p\, q^n \ldots\ldots, \quad (2)$$

each of which series consists of $n+1$ terms.

Conversely, the sums of the series (1) and (2) are known; for they are, respectively, h_{2n} and h_{2n+1}, i. e.,

$$(\alpha^{2n+1} - \beta^{2n+1}) \div (\alpha - \beta),$$

and

$$(\alpha^{2n+2} - \beta^{2n+2}) \div (\alpha - \beta).$$

Finally, h_n is expressed under another form, viz.:—

$$h_n = p^r \cdot h_{n-r} + r \cdot p^{r-1} \cdot q \cdot h_{n-r-1} + \frac{r \cdot (r-1)}{1 \cdot 2} \cdot p^{r-2} q^2 \cdot h_{n-r-2} + \ldots$$

$$+ q^r \cdot h_{n-2r};$$

which may be expressed symbolically thus:—

$$h_n = (p+q)^r \cdot [h]_{n-2r}^{n-r}.$$

II.

If $x^m = p_1 \cdot x^{m-1} + p_2 \cdot x^{m-2} + p_3 \cdot x^{m-3} + \ldots + p_m$, *to express* x^n $(n > m)$ *in form*

$$P_1 \cdot x^{m-1} + P_2 \cdot x^{m-2} + P_3 \cdot x^{m-3} + \ldots + P_m.$$

A particular case is first considered. If $x^4 = px^3 + qx^2 + rx + s$, to express x^n in the form

$$Px^3 + Qx^2 + Rx + S.$$

We may briefly indicate the solution thus:—

Multiplying both sides of equation $x^4 = px^3 + qx^2 + rx + s$ by x, and arranging the terms, we shall find

$$x^5 = h_2 \cdot x^3 + (qh_1 + r)x^2 + (rh_1 + s)x + sh_1.$$

Repeating this process, we shall find by the application of (I)—

$$x^6 = h_3 . x^3 + (qh_2 + rh_1 + s) . x^2 + (rh_2 + sh_1) . x + s . h_2,$$

where h_n is the sum of the homogeneous products of roots of $x^4 = px^3 + qx^2 + rx + s$ of n dimensions.

Finally, it is shown by the process of Mathematical Induction, and the repeated application of (I), that

$$x^n = h_{n-3} . x^3 + (qh_{n-4} + rh_{n-5} + s . h_{n-6}) . x^2 + (r . h_{n-4} + s . h_{n-5}) . x + s . h_{n-4}.$$

The general case is established in a similar way—

$$x^m = p_1 . x^{m-1} + p_2 . x^{m-2} + \ldots + p_m.$$

Multiplying both sides of this equation by x, and arranging the terms, we shall find

$$x^{m+1} = h_2 . x^{m-1} + (p_2 h_1 + p_3) . x^{m-2} + \ldots + (p_{m-1} . h_1 + p_m) . x + p_m . h_1.$$

Repeating this process, we shall find by the application of (I),

$$x^{m+2} = h_3 . x^{m-1} + (p_2 h_2 + p_3 h_1 + p_4) . x^{m-2} + \ldots + (p_{m-1} . h_2 + p_m . h_1) . x + p_m . h_2.$$

Finally, it is shown by the process of Mathematical Induction, and the repeated application of (I), that—

If $x^m = p_1 . x^{m-1} + p_2 . x^{m-2} + \ldots + p_m$, then

$$x^n \ (n > m) = h_{n-m+1} . x^{m-1} + (p_2 . h_{n-m} + p_3 . h_{n-m-1} + p_4 . h_{n-m-2} + \ldots + p_m . h_{n-2m+2}) . x^{m-2} + (p_3 . h_{n-m} + p_4 . h_{n-m-1} + \ldots + p_m . h_{n-2m+3}) . x^{m-3} + \ldots\ldots + (p_{m-1} . h_{n-m} + p_m . h_{n-m-1}) . x + p_m . h_{n-m},$$

where h_n is the sum of the homogeneous products of roots of

$$x^m = p_1 . x^{m-1} + p_2 . x^{m-2} + \ldots + p_m,$$

of n dimensions.

EXPLANATION.

By the "sum of the homogeneous products of $\alpha_1, \alpha_2, \ldots \alpha_m$ of n dimensions" is meant the sum of all the products, each of n dimensions, that can be formed of $\alpha_1, \alpha_2, \ldots \alpha_m$ and their powers.

It is the coefficient of x^n in the development of

$$\frac{1}{1-\alpha_1 x} \cdot \frac{1}{1-\alpha_2 x} \cdot \ldots \cdot \frac{1}{1-\alpha_m x},$$

i. e., in the development of

$$(1+\alpha_1 x+\alpha_1^2 x^2+\ldots)(1+\alpha_2 x+\alpha_2^2 x^2+\ldots)\ldots(1+\alpha_m x+\alpha_m^2 x^2+\ldots)$$

We notice that it includes the *powers* of $\alpha_1, \alpha_2, \ldots \alpha_m$, and it is often expressed more fully thus:—

"The sum of the homogeneous products of $\alpha_1, \alpha_2, \ldots \alpha_m$ and their powers, all of n dimensions."

The *number* of homogeneous products of n dimensions that can be formed out of $\alpha_1, \alpha_2, \ldots \alpha_m$ and their powers is found in the usual way by putting $\alpha_1, \alpha_2, \ldots \alpha_m$ each = 1, and is

$$\frac{\lfloor m+n-1}{\lfloor m-1 \rfloor n}.$$

XLVIII.—On the Satellite of a Line meeting a Cubic. By William R. Roberts, M. A.

[Read, April 12, 1880.]

Before entering on the discussion of the equation of the satellite and that of the tangent at the three points in which a given line meets a cubic, it will be found convenient to premise the following theorem:—

Given the equations of two curves of the p^{th} and q^{th} order, respectively,

$$(1). \quad \phi(x\ y\ z) = 0,$$

$$(2). \quad \psi(x\ y\ z) = 0,$$

to form symmetric functions of the pq values which simultaneously satisfy the two equations. Eliminating $x\ y\ z$ between (1) and (2), and the equation of an arbitrary line $lx + my + zn = 0$, we obtain an equation of the pq^{th} degree in $l\ m\ n$, which may be written

$$\Lambda(\phi, \psi) = A_{pq,0,0}\, l^{pq} + A_{pq-1,1,0}\, l^{pq-1} m + \ldots \text{ \&c.};$$

then we shall have—

$$A_{pq,0,0} = \kappa . x_1 x_2 \ldots x_{pq};$$

$$A_{pq-1,1,0} = \kappa . \Sigma\, y_1 x_2 x_3 \ldots x_{pq};$$

$$\text{\&c.,} \qquad \text{\&c.}$$

Having found these fundamental symmetric functions, the formation of others presents no difficulty.

Let $T = 0$ be the equation of the tangents at the points where $L \equiv \lambda x + \mu y + \nu z$ meets the cubic $U \equiv x^3 + y^3 + z^3 + 6mxyz$, then we must have—

$$T \equiv \Sigma U - KL^2M,$$

where Σ is the condition that L should touch U and $M \equiv \lambda' x + \mu' y + \nu' z$ is the satellite of L. For, when L touches U, T must reduce to the product L^2M multiplied by a numerical factor K.

The polar conic S of any point $x'y'z'$ on T, U, and L, all pass through a common point. Hence the eliminant of S, L, and U, equated to zero, will express that $x'y'z'$ lies on T. Or,

$$T \equiv (x_1^3 + y_1^3 + z_1^3 + 6m\, x_1 y_1 z_1)(x_2^3 + y_2^3 + z_2^3 + 6m . x_2 y_2 z_2);$$

$x_1 y_1 z_1$, $x_2 y_2 z_2$ being values common to S and L. It will be sufficient

for our purpose to calculate the coefficient of x'^3 in T. Forming the equation $\Lambda(S, L)$, and putting $y' = z' = 0$, we find—

$$\begin{aligned} x_1 x_2 &= -2m\mu\nu x', \\ y_1 y_2 &= \nu^2 x', \\ z_1 z_2 &= \mu^2 x', \\ y_1 z_2 + z_1 y_2 &= -2(\mu\nu + m\lambda^2) x', \\ z_1 x_2 + z_2 x_1 &= 2m\lambda\mu x', \\ x_1 y_2 + y_1 x_2 &= 2m\lambda\nu x'. \end{aligned}$$

The coefficient of x'^3 is found to be—

$$\begin{aligned} &\mu^6 + \nu^6 - (2 + 32m^3)\mu^3\nu^3 - 18m\lambda^2\mu^2\nu^2 \\ &\quad - 24m^2\lambda\mu\nu(\lambda^3 + \mu^3 + \nu^3) - 8m^3\lambda^6 \\ &\quad - 16m^3\lambda^3(\mu^3 + \nu^3). \end{aligned}$$

Now,

$$\begin{aligned} \Sigma = {} & \lambda^6 + \mu^6 + \nu^6 - (2 + 32m^3)(\lambda^3\mu^3 + \mu^3\nu^3 + \nu^3\lambda^3) \\ & - 24m^2\lambda\mu\nu(\lambda^3 + \mu^3 + \nu^3) - (24m + 48m^4)\lambda^2\mu^2\nu^2. \end{aligned}$$

Substracting the above quantity from Σ, we find—

$$K\lambda^2\lambda' = (1 + 8m^3)\lambda^2\{\lambda^4 - 2\lambda(\mu^3 + \nu^3) - 6m\mu^2\nu^2\}.$$

Hence,

$$\begin{aligned} K &= (1 + 8m^3), \\ \lambda' &= \lambda^4 - 2\lambda(\mu^3 + \nu^3) - 6m\mu^2\nu^2, \\ \mu' &= \mu^4 - 2\mu(\lambda^3 + \nu^3) - 6m\nu^2\lambda^2, \\ \nu' &= \nu^4 - 2\nu(\mu^3 + \lambda^3) - 6m\lambda^2\mu^2. \end{aligned}$$

The form of these co-ordinates at once suggests the following theorem :—

The satellite of a given line, meeting a system of cubics passing through the inflexions of U, passes through a fixed point.

XLIX.—On the Directions of Main Lines of Jointing observable in the Rocks about the Bay of Dublin, and their Relations with adjacent Coast Lines.

By J. P. O'Reilly, C.E., Professor of Mining and Mineralogy, Royal College of Science, Ireland.

[Read, February 23, 1880.]

When submitting to the Academy, in January, 1879, a memoir upon the correlations of lines of direction on the Earth's surface (vide *Transactions*, vol. xxvi., p. 617), I expressed the hope of being able to bring forward a series of observations in support of the theory therein involved, to be taken, in the first place, from the three kingdoms, the Geology of which has been so thoroughly worked out in most of its details.

During the last two summers I made a series of determinations of directions of main lines of jointing, on the north and south sides of the Bay of Dublin, which I have the honour of submitting to the Academy, with a summary of the consequences which I think are fairly deducible therefrom, and which go in support of the general theory of correlation already referred to.

I have in the first place simply detailed the measurements and observations made, and have then grouped the directions of jointing into series, showing their relations one with the other and with the coast lines.

Commencing at Blackrock, the most northerly outcrop of the Dalkey or Wicklow granites, there occur on the shore, just beside the railway station, patches of granite which extend out in small promontories in a N.E. direction.

One patch of this rock occurs close under the Blackrock station, and forms there part of the sea wall. It presents the constitution of a well-marked granitic Breccia[1] which has not, that I am aware of, any representative in or about the Dublin coast. It evidently represents the consequences of a fracture having taken place in the immediate vicinity, and is in all probability related to the cause which determined the northern limit of the Dalkey granites. This is to a certain extent indicated by the direction[2] of the jointing observed in this granite :—

Blackrock :—

1.	General direction in a rough joint, ...	Nm.	67° W.
2.	Cross jointing, ...	,,	13° E.
3.	Jointing in rocks at ladies' bathing-place, under Idrone-terrace, ...	,,	67° W.
4.	Another jointing in the same place, ...	,,	67° W.

[1] See "Notice of some Remarkable Appearances of the Granite to the South of Dublin," by the Rev. H. Lloyd, F.T.C.D., M.R.I.A., *Proc.* Geol. Soc.: Dublin, Nov. 10, 1833.

[2] The directions in this Table are magnetic. The magnetic variations being, for the date of the observations, about 22° W.

People's Park, Blackrock :—

5.	Joint in granite about 100 yards west of path up to Rock-road,	Nm.	53° E.
6.	Jointing further west,	,,	44° E.
7.	General direction of jointing,	,,	48°–50° E.

Seapoint :—

8.	To the west of the Martello Tower and opposite the Terrace, repeated vertical jointing in the granite,	,,	44° E.
9.	Joint at corner beside the Tower,	,,	12°–13° W.
10.	Martello Tower, joint at,	,,	20°–23° W.

Salthill :—

11.	At stairs between Martello Tower and Salthill Station, well-marked joint parallel to Railway,	,,	50° 30′ W.
12.	About 45 yards north of the stairs,	,,	68° W.
13.	Jointing just beside bathing place at Salthill,	,,	48°–50° W.
14.	,, further to the north at this point,	,,	47°–49° W.

Kingstown :—

15.	Victoria Baths, Eurite jointing at,	,,	86° W.
16.	,, ,, under old Battery,	,,	14° E.
17.	120 yards east of old Battery,	,,	32° 30′ E.
18.	,, ,, ,,	,,	62° 30′ W.
19.	,, ,, ,,	,,	11°–12° E.
20.	Near St. Alban's, shore of Scotchman's Bay, well-marked jointing,	,,	15° E.
21.	,, ,, ,, ,, ,, ,,	,,	39° E.
22.	100 yards east of St. Alban's,	,,	11° E.

Scotchman's Bay :—

23.	Between St. Alban's and Sandycove, at about 160 yards east of St. Alban's, jointing,	,,	60° W.
24.	,, ,, ,, ,, ,, ,,	,,	64° W.
25.	,, ,, ,, ,, ,, ,,	,,	16° 30′ W.

Sandycove :—

26.	Just north of Battery,	,,	28° W.
27.	,, ,, ,,	,,	57° E.
28.	,, ,, ,,	,,	46° E.
29.	To the east of the Battery, vertical and repeated,	,,	35° W.
30.	Under Martello Tower,	,,	24° E.
31.	About 100 yards east from Tower,	,,	61° 30′ W.
32.	,, 300 ,, ,, ,,	,,	65° W.
33.	About 300 yards west of Bullock Harbour, well-defined gaping joint,	,,	44° E.

Bullock Harbour :—

34.	North-east corner, three well-marked joints,	,,	27° E.
35.	,, ,, well-marked joint,	,,	7°–8° E.
36.	,, ,, north of last, a well-marked joint,	,,	27° E.
37.	,, ,, another,	,,	27° E.
38.	At end of yard, to east of coal-yard and next it, great open joint, 2m. broad and 3m. at mouth; slight dip east,	,,	38°–39° E.

Kingstown Quarry at Victoria Baths:—

39.	Victoria Baths, quarry opposite to, two lodes or dykes well marked, at north-west corner, . .	N$^{m.}$	67° W.
40.	Joint in same place, ...	,,	67°–68° W.
41.	,, ,, ,, ...	,,	19°–20° E.
42.	,, ,, ,, ...	,,	63° W.
43.	At south-east corner, well-marked face, 19$^{m.}$ long,	,,	38°–39° W.
44.	Jointing here, ...	,,	41°–42° E.
45.	,, ,, in east side, ...	,,	31°–33° E.
46.	,, ,, ,, ...	,,	57°–58° W.
47.	,, ,, ,, ...	,,	43°–44° W.

Bullock Quarry:—

48.	Joint on north side, ...	,,	48°–49° W.
49.	,, south side, ...	,,	53°–55° W.
50.	,, ,, ...	,,	49° W.
51.	At east end, Eurite vein, ...	,,	51°–52° E.
52.	,, ,, Quartz vein, 16 inches wide, . .	,,	37°–38° W.

Dalkey:—

53.	Old quarry at Trafalgar-row, jointing in, . .	,,	38° W.
54.	,, ,, ,, ,, . .	,,	42° W.

Sorronto Terrace:—

55.	Under Dr. M'Donnell's house, Quartz and Eurite bands in rocks along south side of Terrace, .	,,	28° 45′ W.
56.	,, ,, ,, ,, ,, ,, .	,,	18°–20° W.
57.	,, ,, ,, ,, ,, ,, .	,,	45° 30′ E.

Dalkey:—

58.	Tunnel at Khyber Pass, joint at south side of Railway,	,,	23°–25° W.
59.	,, ,, at about 10$^{m.}$ west of this, .	,,	25°–26° W.

Killiney:—

60.	On shore, at about 250 yards east of Dr. M'Donnell's house, ...	,,	25° W.
61.	Repeated jointing, ...	,,	28° W.
62.	,, ,, ...	,,	87° E.
63.	Very repeated cross jointing here, . . .	,,	31° 45′ E.

Long Rock:—

64.	Bathing place, extremely well-marked jointing and dyke, ...	,,	27° 30′ W.
65.	,, ,, ,, ,, ,, ,, .	,,	29° 30′ W.
66.	Cross jointing, ...	,,	34° E.

Torquay Hill:—

67.	Several parallel joints, well marked, . . .	,,	28° 30′ W.
68.	Cross jointing repeated, ...	,,	33° E.
69.	Ridge, 200 yards east of Old Telegraph, . .	,,	18° W.

Killiney Hill:—

70.	In depression to east of old Telegraph, . .	,,	32° 30′ W.
71.	Between old Telegraph Hill and Obelisk, well-marked Eurite vein in, ...	,,	33° W.
72.	Another, ...	,,	25° W.
73.	,, ...	,,	18° W.

Killiney Hill—*continued.*

74.	Depression between old Telegraph Hill and Obelisk Hill, general direction, ...	N^{m}·	8°–10° E.
75.	On road at Killiney House, contact of granite and mica schist, ...	,,	46° E.
76.	40 yards west of entrance to Killiney Castle, great Eurite dyke, vertical and much banded, . .	,,	24° E.

Killiney Park:—

77.	Contact of granite and slate rock, fault (the direction of the contact line runs out between the two Sugar-loaves), ...	,,	39° E.
78.	Joint cutting off the banded granite or gneiss to the east, ...	,,	47°–50° E.
79.	Contact of granite and slate rock at western end in park, ...	,,	42° E.
80.	Contact direction taken on a line 4^{m}· from face of joint and parallel to it, about 30 yards long, .	,,	39°–40° E.
81.	Eurite vein on west side of Park, apparent direction,	,,	26° W.
82.	,, ,, to the west, near the new Quarries, .	,,	26° W.
83.	Band of Euritic granite here, ...	,,	27° W.
84.	Face of granite joint, well marked, as if of bedding (dip south at 62°), ...	,,	25° W.
85.	Eurite band here, ...	,,	54° W.

Dalkey Island:—

86.	East of Boat Harbour, repeated vertical jointing, .	,,	70° W.
87.	,, ,, ,, great Eurite vein, vertical, 0^{m}·50–0^{m}·80 thick, .	,,	6°–7° W.
88.	,, ,, ,, joint further east, . .	,,	6°–7° W.
89.	,, ,, ,, set of joints, . . .	,,	26°–28° E.
90.	,, ,, ,, ,, ,, . . .	,,	28°–30° E.
91.	,, ,, ,, big joint looking towards Bailey Light-house, .	,,	38°–40° E.
92.	On east side, north-east point, joint, . . .	,,	43° E.
93.	Near easternmost point, two joints at an interval of 3^{m}·, ...	,,	42°–43° E.
94.	North-east point, opposite Muglins, set of quartz joints, ...	,,	7°–8° W.
95.	,, ,, ,, Eurite vein with felspar crystals,	,,	23°–24° W.
96.	,, ,, ,, vertical joint at same point, .	,,	7°–7° 30′ W.
97.	Near rocking stone in little inlet, Eurite vein 0^{m}·50 thick, vertical, . . .	,,	22° 30′ W.
98.	,, ,, ,, Eurite vein close by, . .	,,	28°–30° W.
99.	Jointing parallel to south-east coast line, . .	,,	37°–38° E.
100.	Just under Battery, Eurite vein, 1^{m}· thick (a series of these extending to the south-west shore line),	,,	18°–19° W.
101.	Between Martello Tower and Battery, jointing, .	,,	30° E.
102.	Under Martello Tower, jointing, ...	,,	48°–49° E.
103.	,, ,, ,, ,, ...	,,	16°–17° E.
104.	Near south corner of enclosed field, . . .	,,	58° E.
105.	North corner ,, ,, ,, . . .	,,	51° E.

Dalkey Railway :—

106.	Between the two bridges, east of Sandycove Station, on north side, vertical jointing, . . .	Nm.	7°–8° W.
107.	At bridge, 100 yards west of Glenageary Church, .	,,	18°–23° W.
108.	,, ,, ,, on north side of line, well-marked joint, with slight dip to south, .	,,	23° W.
109.	East of bridge, at Glenageary Church, repeated jointing, slight dip to east, ...	,,	39° E.
110.	,, ,, ,, ,, ,, .	,,	36° E.
111.	,, ,, ,, ,, ,, .	,,	42° E.
112.	40 yards east of bridge, vertical jointing, . .	,,	48° W.

Dalkey :—

113.	Entrance to old Quarries, Dalkey, north-west side, great face of rock, ...	,,	20°–22° E.
114.	,, south-east side, great face of rock, .	,,	2°–3° E.
115.	,, south-west side, ,, ,, ,, . .	,,	7°–8° W.

Dalkey Quarries :—

116.	East side of eastern quarry, vertical face, . .	,,	10°–12° W.
117.	,, ,, ,, another, vertical face,	,,	21° W.
118.	,, ,, ,, general direction, .	,,	18° W.
119.	Eastern quarry, south-east corner, great vertical face,	,,	18° W.
120.	,, ,, 20 yards from south-west corner, vertical joint, with quartz vein,	,,	18°–19° W.
121.	,, ,, vertical cross jointing, apparently,	,,	58°–59° E.
122.	,, ,, west side, south end, great face, .	,,	12°–13° W.
123.	,, ,, ,, towards middle ,, .	,,	11°–12° W.
124.	,, ,, ,, at north-west end, face,	,,	5° W.
125.	,, ,, cross jointing, at south end, rough and broken, ...	,,	54°–55° E.
126.	Middle lower Quarry, north-east side, vertical face,	,,	21°–22° W.
127.	,, ,, ,, outcrop on ground,	,,	21° W.
128.	,, ,, south-east side, great vertical face, ...	,,	12°–13° W.
129.	,, ,, south-west side, great central rib, under old Telegraph, .	,,	18° W.
130.	,, ,, Eurite vein, on continuation of this, ...	,,	17°–18° W.
131.	,, ,, ,, ,, ,, .	,,	21°–22° W.
132.	,, ,, ,, ,, ,, .	,,	17°–18° W.
133.	,, ,, west side, joint near Eurite vein, dip east, . . .	,,	22°–24° W.
134.	,, ,, west side, Eurite vein, dip east,	,,	25°–26° W.
135.	,, ,, ,, joint more to west, with same dip, . .	,,	25°–26° W.
136.	,, ,, ,, great Eurite vein, 0m·30 thick, dip west, .	,,	21°–22° W.
137.	,, ,, ,, cross jointing, . .	,,	42°–43° E.
138.	,, ,, ,, great vertical face, .	,,	17°–18° W.
139.	,, ,, north-west point, Eurite vein,	,,	26°–27° W.
140.	Upper Quarry, great Eurite vein, 0m·25 thick, under old Telegraph, ...	,,	26°–27° W.
141.	,, ,, another in same place, . . .	,,	13° 30′–14° W.
142.	,, ,, great Eurite vein, 2m·50 thick, dipping east, running approximately in direction of Blackrock P. Church,	,,	28° 30′ W.
143.	,, ,, ,, ,, ,, ,, .	,,	30° W.

Dalkey Quarries—*continued.*

144.	Upper Quarry, 6–7 yards west, great dyke of feldspathic porphyry,	Nm.	44° W.
145.	,, ,, quartzite vein,	,,	18° W.
146.	,, ,, 10 yards west of this joint,	,,	21° W.
147.	Lower west Quarry, north-west point, joint,	,,	13° E.

Carrickmines :—

148.	Joint in granite, 400 yards south of Station, in furze field,	,,	2° W.

The Dingle :—

149.	Jointing of rock in, on east side,	,,	Nm.
150.	On west side, beside cottage, cross jointing,	,,	63°–64° W.

Carrickmines :—

151.	Lode, north of smoke stack,	,,	57° W.

Scalp :—

152.	In wood, on east side, jointing in slate rock,	,,	4° W.
153.	Jointing in granite face, on east side,	,,	4° W.

Howth :—

154.	Balscaddan Bay, quartz vein in highly altered slate rocks, 220 yards east of bathing-place,	,,	29° E.
155.	,, ,, south side of detached rock called "The Stag,"	,,	84°–85° W.
156.	Puck's Rocks, well-marked joint in,	,,	6° E.
157.	,, ,, apparent dyke in more easterly rock,	,,	46°–47° E.
158.	,, ,, joint near this,	,,	16° E.
159.	,, ,, cross jointing,	,,	59° W.
160.	Kitestown, joint in slate rock, in recess near private house,	,,	5°–6° W.
161.	Dung Hill (second hill from west, on west side, opposite plantation), apparent jointing on west side with quartz and Eurite jointing,	,,	14° E.
162.	,, ,, on top of hill, in a mass of Euritic-looking rock jointing,	,,	4° W.
163.	,, ,, ,, ,, ,, ,,	,,	4° W.
164.	,, ,, ,, ,, ,, ,,	,,	Nm.
165.	,, ,, north-west extremity of, iron ore lode well marked (corresponds with direction of top of Ireland's Eye and west slope of Lambay Island),	,,	40°–44° E.
166.	Red Rock, near cottage, in entrance of a well-marked depression, 250 yards west of Candle-house, well marked face of jointing,	,,	69°–70° W.
167.	,, ,, cross jointing, apparently,	,,	4°–5° E.
168.	,, ,, to the east of this, in dell, jointing,	,,	37° E.
169.	,, ,, this boss of altered slate rock traversed by well-marked vertical joints,	,,	12°–13° E.
170.	,, ,, ,, ,, ,, ,,	,,	12° E.
171.	At Carrickbrack House, at bend of road, joint,	,,	74°–75° E.
172.	,, ,, cross jointing,	,,	8°–10° W.
173.	,, ,, well-marked jointing here, dip to east,	,,	36°–37° E.

Howth—*continued.*

174.	Loughoreen Hills, mass of rock facing plantation, vertical jointing, in Euritic-looking rock, with much quartz and red oxyde of iron, . .	N$^{m.}$	5° W.
175.	,, .. on top of rock, quartz veins, nearly vertical, Euritic-looking mass, ...	,,	67°–68° E.
176.	Cromlech Dell, jointing running across dell, .	,,	72°–73° W.
177.	,, ,, another system of joints, . .	,,	37° E.
178.	,, ,, cliff side in dell, ...	,,	23°–24° E.
179.	,, ,, jointing, cutting off north-west point of Muck Rock (passes over summit of Ireland's Eye and Lambay), ...	,,	37°–38° E.
180.	Sutton, Dolomites at Sutton quay, life-boat station, well-marked vertical jointing, .	,,	36°–37° E.
181.	,, ,, ,, ,, at another point,	,,	41°–42° E.
182.	,, .. on surface of Dolomite, . .	,,	38°–39° E.
183.	,, ,, cross jointing, ...	,,	1° E.
184.	,, ,, another system of, . . .	,,	68°–69° W.
185.	,, ,, ,, ,, . . .	,,	3° W.
186.	,, ,, ,, ,, . . .	,,	6°–7° W.
	,, The Dolomite cut off and abutting against decomposed quartzites, 50–60 yards west of Coast-guard Station.		
187.	,, Coast-guard Station, jointing in slate rock, under flag-staff of, ...	,,	21° W.
188.	,, little promontory east of Coast-guard Station (near Bottle Quay), the slate much broken and jointed vertically, . .	,,	60° E.
189.	,, quartz veining, very frequent here, cuts previously mentioned joint nearly vertically,	,,	70°–73° W.
190.	,, vertical joint cutting these, not very marked,	,,	33° E.
191.	,, to the east of last-mentioned point, well-marked, frequent and vertical jointing, .	,,	39° E.
192.	,, ,, further east, ...	,,	28° W.
193.	,, 250 yards west of Martello Tower, great joint in slate rock filled with quartz veins, indistinct in the true slates, . . ,	,,	25°–35° W.
194.	,, about 100 yards west of Martello Tower, well-marked quartzose veins in the slate, dipping at a high angle north-east, .	,,	24° E.
195.	,, frequent and vertical jointing, cutting all these green slates, ...	,,	7° W.
196.	,, Martello Tower, mass of quartzite, on which the tower built, much fissured, west side,	,,	87° W.
197.	,, ,, ,, ,, ,, ,, .	,,	82°–85° W.
198.	South side, Martello Tower, on east side, 12 yards from it, well-marked vertical jointing, .	,,	90° E.
199.	,, ,, ,, cross jointing, well marked and vertical, . . .	,,	4°–5° W.
200.	,, cross jointing, well marked, . . .	,,	43° E.
201.	,, (forms the little creek just under Tower), .	,,	38°–39° E.
202.	,, 60 yards east of tower cave, joint, . .	,,	15°–18° E.
203.	,, 150–180 yards east of Tower, immense jointing, giving rise to a cave, . .	,,	50° W.

Howth—*continued.*

204.	South side, 300–400 yards east of Tower, splendid vertical jointing, ...	Nm.	3°–4° W.
205.	,, ,, ,, ,, ,, ,, .	,,	2°–3° W.
206.	,, ,, ,, ,, vertical jointing, cutting shore here less distinctly marked,	,,	21° E.
207.	,, ,, ,, ,, ,, ,, .	,,	23° E.
208.	,, 120 yards east of Tower, joint apparently a fault with cave, ...	,,	28° W.
209.	,, 450 yards east of Tower, vertical jointing in red rock, well marked, ...	,,	8° E.
210.	,, ,, ,, ,, ,, jointing,	,,	29° E.
211.	,, 500 yards east of Tower, jointing, . .	,,	38° W.
212.	,, ,, ,, cave joint on fault, .	,,	27°–28° E.
213.	,, great joint further east, 1m· wide in places, having caused fall of surface rocks, distant from previous joint about 20–25 yards,	,,	28° E.
214.	,, about 525 yards east of Tower, cross jointing, dipping east, ...	,,	88° E.
215.	,, a series of great joints occur here at short intervals, ...	,,	26°–28° E.
216.	,, another system of jointing, well marked, dipping east, ...	,,	43° E.
217.	,, east of Drumleck Point, Little Boat Harbour, frequent and well-marked vertical jointing, ...	,,	16° E.
218.	,, near the Boat Harbour, to the east, occurs a great open joint, cut down to low water, 5 feet broad at bottom, formed by previous jointing with another, . . .	,,	3° W.
219.	,, about 250 yards east from boat-house, jointing in a mass of quartzite, . .	,,	20. E.
219bis.	,, ,, ,, ,, ,, ,, .	,,	18° E.
220.	,, vertical quartz veins in, ...	,,	82°–85° E.
221.	,, about 400 yards east from boat-house, frequent and vertical jointing, indenting the coast line, ...	,,	3° W.
222.	,, 250 yards south-west from Tansey House, frequent vertical jointing here, . .	,,	21° E.
223.	,, about 80 to 100 yards east from this point, great fault dislocating the ground, dip east at 75°–80°, ...	,,	38°–39° E.
224.	,, crossed by jointing, (accompanied by a band of decomposed trap rock), . .	,,	3°–5° W.
225.	,, "Sheep-hole" cave and little inlet, the cave apparently on a greenstone dyke, dipping east, ...	,,	36°–38° E.
226.	,, creek to east of "Sheep-hole," vertical lode or joint on west side of, 0m·50 at ground surface, ...	,,	35°–38° E.
227.	,, west side of Drumleck Point, at about 50-60 yards east of previous point, well-marked jointing, dipping east, at angle of 60°–70°, ...	,,	39° E.
228.	,, vertical jointing in quartzite, to the east of this point, ...	,,	11° E.
229.	,, jointing in this quartzite, . . .	,,	17°–18° E.
230.	,, cross jointing, frequent and vertical, .	,,	7°–8° W.

Howth—*continued.*

231.	South side, east of bathing-place, at point called the "Worn-hole," vertical quartz veins, very distinct with parallel ones, . .	Nm.	23°–24° E.
232.	,, opposite dwelling-house, joint dipping east,	,,	7°–8° W.
233.	,, about 350 to 400 yards east of bathing-place, great vertical joint, 3 feet broad in an apparently altered rock, greatly weathered, ...	,,	33°–34° W.
234.	Drumleck Point, east of great fissure in greenstone rock, ...	,,	5° W.
235.	,, cross jointing, ...	,,	67°–68° W.
236.	,, Bay, west side of, vertical joint, . .	,,	47°–48° W.
237.	,, "Broad Strand," immense face of jointing on east side of bay, extending from top to bottom of cliff, ...	,,	3°–5° W.
238.	,, "Lion's Head," little promontory near the Bailey Light, ...	,,	39° E.

Ireland's Eye :—

239.	Fault in slate rock, towards south-east point, .	,,	87°–88° E.
240.	At south-east point, in black mica slates (Thulla Rocks), ...	,,	13°–14° E.
241.	On south-east side, just south of first creek, in slate rocks, jointing in, ...	,,	43°–44° W.
242.	The west side of first creek and east side of the detached rock called "The Stag," . . .	,,	36°–37° E.
243.	North of Rowan's Rocks, in little creek on east side, cross jointing at the entrance, ...	,,	73°–74° W.
244.	Jointing running across the mouth of same, nearly vertical, ...	,,	3°–5 W.
245.	East side, apparent contact of quartzite with dark shales (Samphire Hole), ...	,,	68°–70° W.
246.	In Samphire Hole, ...	,,	50°–60° W.
247.	In cave, ...	,,	50°–56° W.
248.	North-east point, well-marked vertical jointing in quartzite under "Stags," . . .	,,	75°–76° W.
249.	,, vertical joint frequent and well marked, apparently parallel to axis of gut between "Stags,"	,,	3°–5° W.
250.	Middle of Island, to the north, jointing in boss of white quartzite, ...	,,	84°–85° W.
251.	300 yards east of Martello Tower, well-marked vertical joint, with slight dip to west in quartzite, ...	,,	53° E.
252.	,, ,, well-marked cross jointing, running towards Tower, . . .	,,	32°–33° W.
253.	,, well-marked jointing, running towards Skerries, ...	,,	26°–27° W.
254.	Apparent contact face of quartzites with altered shales, 100 yards north of St. Nessan's Church, ...	,,	77° W.

Howth :—

255.	Centre of Hill, jointing in slate rock, much broken and weathered, ...	,,	71° E.
256.	,, ,, ,, ,, ,, .	,,	69° E.
257.	,, trench opened on jointing, . . .	,,	38°–40° E.

The foregoing observations having been grouped relatively to direction, the mean true direction corresponding to each group having been taken, and a classification according to frequency of occurrence of each direction having been made, there resulted the following Table :—

JOINTS AND LINES OF DIRECTION GROUPED AND REDUCED TO TRUE BEARINGS.

EASTERLY.				WESTERLY.			
Relative Rank as to Frequency.	Direction.	Number observed.	Total.	Relative Rank as to Frequency.	Direction.	Number observed.	Total.
14	1° 55′ E.	6		20	1° 54′ W.	5	
11	5° 43′ ,,	9		15	5° 26′ ,,	6	
12	10° 19′ ,,	7		9	9° 27′ ,,	10	
1	16° 23′ ,,	26		21	14° 17′ ,,	5	
4	21° 20′ ,,	13		31	21° 40′ ,,	3	
29	25° 50′ ,,	3		2	25° 52′ ,,	19	
25	30° 08′ ,,	4		5	29° 11′ ,,	12	
18	35° 36′ ,,	5		22	34° 27′ ,,	5	
28	48° 30′ ,,	4		6	39° 57′ ,,	12	
26	66° 08′ ,,	4		3	43° 51′ ,,	14	
33	61° 30′ ,,	1		10	47° 42′ ,,	10	
19	72° 35′ ,,	5		8	50° 12′ ,,	11	
32	81° 45′ ,,	2		23	59° 24′ ,,	5	
30	85° 10′ ,,	3	92	27	65° 15′ ,,	4	
				12	70° 39′ ,,	7	
				16	78° 15′ ,,	6	
				17	84° 55′ ,,	6	
				7	89° 45′ ,,	12	152

Ranging the more important of those directions, relatively to their frequency of occurrence, we have the following series :—

1	16° 23′ E.	26 occurrences.	7	89° 46′ W.	12 occurrences.
2	25° 52′ W.	19 ,,	8	50° 12′ W.	11 ,,
3	43° 51′ W.	14 ,,	9	9° 27′ W.	10 ,,
4	21° 20′ E.	13 ,,	10	47° 42′ W.	10 ,,
5	29° 12′ W.	12 ,,	11	5° 43′ E.	9 ,,
6	39° 59′ W.	12 ,,			

There now remains to be shown the relations which those directions bear to the coast lines on the east side of Ireland; and, furthermore, their relations with the lines of directions corresponding to the principal mountain chains, river valleys, main lines of jointing, and geological lines of boundary of the interior of the country.

Taking the first direction, 16° 23′ E., the mean of twenty-six observed directions (but not necessarily the mean of all the similar directions which might be observed in Ireland), it will be found that this is the direction of the coast line between Carnsore Point and Wicklow Head, as exactly as possible; also the line of direction between Carmel's Point, N. W. Wales, and St. David's Head, S. W. Wales. It also represents the boundary line limiting the granite of Wicklow, on the west side, between Castledermot and Goresbridge, and the general direction of the mountains between Kippure and Achavannagh mountains, as shown on Griffith's general map of Ireland. It represents, therefore, a coast line and a line of mountain direction. It also represents a band, or zone, of parallel joints which must extend over a considerable distance, and over a certain breadth of country. If we examine the extension of this direction on the map of Great Britain, it will be found to pass through the Mull of Galloway, near Cairngarroch Bay, to pass at Ayr, Ben Mac Dun chain, and to come out at Elgin—this direction being that of the north-east coast of Scotland, between Fifeness and Peterhead. The continuation of the line of direction passes through the Shetland Islands, on the western side, parallel to their general or longer axis, and to the geological boundary line of the southern promontory of Mainland Island. If it be further examined, with reference to the Great Circle of which it forms a part, it will be found that its extension traverses the Northern Ocean, parallel to a line joining Bremanger Land (the most westerly point of Norway) with Great Ice Cape (the north-east point of Nova Zembla), at about a distance of 3° 47′ from those two extreme points. It then crosses Siberia from the mouth of the Lena to Okhotsk, where it emerges, making with the coast lines east and west angles of about 70°. It traverses the North Pacific, crosses New Caledonia, passes through New Zealand, from Mount Cook to Dunedin, and finally cuts the west coast of Africa, from Bathurst to Cape Bojador. If we compare the extent of land traversed to that of ocean surface, it will be found that these extents stand to one another somewhat in the ratio of 1 : 15; that is to say, that this Great Circle is one of considerable contraction of the surface towards the Earth's centre, and it will be easily recognised that there are not many other Great Circles of greater contraction. Its importance, physically and geologically, has, therefore, a certain significance, lying, as the line or Great Circle does, on the boundary between the Old and New World.

The second direction, 25° 52′ W., is remarkable from more than one point of view. As a coast direction it only shows itself about Killiney, representing the axis of Dalkey Sound, and the depression between the first and second Hills, or between the Telegraph and

Dalkey Hills. It is well and markedly represented by the Scalp, and by the Dingle, to the north-east of the Scalp. It is, however, well marked in the Mourne Mountains, as shown by the Survey maps, and fairly represents the north-east coast line of Ireland, between Burial Island and Rathlin Island, coinciding with the coast line between Donaghadee and Long Rock, Co. Down. This joint system is nearly everywhere vertical, and in some places very distinct. Its extension northwards is very remarkable, passing through Iceland, near Hecla, according to a direction which is that of the north-west coast of the great inlet or bay called Hunaflood, or Bear Cub Flood, and which is also that of many of the inlets between Portland and Ingolfshead, on the south-east coast line. It crosses North Western America, from Cape Lyon, on the north side, to Mount Fairweather, on the Pacific side; passes between Honolulu and Woahoo (Sandwich Islands); passes New Zealand to the east, and nearly parallel to the axes of the islands: through Enderby's Land; cuts the south coast of Africa at Algoa Bay; traverses Africa, parallel to a line joining the Cape of Good Hope with Cape Lopez Gonsalvez; cuts the river Congo, at Stanley's Pool, that is, about 0° 30′ east of the Kalulu Falls; passes at Algiers, and, crossing the Mediterranean, enters Spain at Tarragona; crosses the Pyrenees; passes at Rochelle, St. Malo, Startpoint, Bideford Bay, and the south-west promontory of Wales. If the line between Beechy Head, in the south, and Cape Wrath, in the north, be taken as about the longest axis of Great Britain, it will be seen that the direction of this axis is about that of the direction under consideration: it will indeed be found to represent sufficiently closely the line joining the coast of Yarmouth with the coast line at Peterhead. It may, therefore, be considered as having a representative character.

The direction 43° 51′ W. is represented by only short stretches of the eastern Irish coast line, such as the south side of the Bay of Dublin, and the line between Skerries and Balbriggan. It also corresponds with portions of the Trap dykes north-east of Lough Erne, with the longer axis of this lough, and with the direction of the Trap dyke marked as running between Maghery Bay and Trawenagh Bay, Co. Donegal. Outside Ireland, the corresponding Great Circle passes through a number of very interesting points; but it may be sufficient to remark, that passing through Monmouthshire, it represents very closely many of the numerous faults characterising the South Wales coal-field, as may be seen by the Geological Survey of the district.

The direction 21° 20′ E. is represented by parts of the south-east coast of Ireland, the outline of which it goes to form, in combination with the direction 16° 23′ E. It also represents the direction of the Downpatrick coast, and the coast line extending between Corsewell Point and Ayr, in Scotland. Furthermore, it may be taken as representing in direction the longer axis of Ireland—that running from Mizen Head to Malin Head, and thus passing through Lough Fergus, on the Shannon, according to its longer axis, and defining the western limit of the middle carboniferous limestone. As a Great Circle direc-

tion, it has nearly the same interest, and passes through the same countries nearly, as the direction 16° 23′.

The only other directions to which attention may be more particularly called are the directions 89° 45′ W.; 9° 27′ W.; and 5° 45′ E.

The direction 89° 45′ W. is represented at Dublin by the jointing in the granite rocks which occur at Blackrock, and which are the most northerly outcrops of the rock. Its continuation across Ireland, from that point, brings it out at Galway, and there corresponding with certain portions of the granite coast line. It represents the line of least elevation crossing Ireland from east to west, and is roughly represented farther south by the line which would pass from Carnsore Point to the Great Blasket Islands. It may be taken as the direction of the axis of the Liffey valley.

The direction 9° 27′ W. represents fairly the coast line between Wicklow Head and Dunany Point, in the Co. Louth; and its continuation passes through the Mourne Mountains, along a portion of the west side of Lough Neagh, and comes out on the coast of Antrim, near the promontory of Portrush. The angle of 40° with this gives a direction which corresponds very closely with that of the Caledonian canal, while the direction 70° with the canal takes in Fifeness, Bamborough Head, and the coast line between Foulness and Yarmouth.

This same direction, ...	9° 27′ W.
gives with the direction, ...	30° 08′ E.
(so remarkable at Ireland's Eye), an intersection of	39° 35′

Lastly, the direction 5° 43′ E. represents the portion of the coast line between Baldoyle and Rush; but more particularly represents the direction of the Great Circle which I had traced, *à priori*, on the globe as the "*West Coast of Portugal*," and which is represented by well-marked faulting in three or four places, by hill direction, and by the east side of Rathlin Island.

As regards the eastern coast of Ireland, it may be fairly advanced that it is represented by directions which correspond to lines of jointing observable, in greater or lesser number, about the Bay of Dublin, and which are as follows:—

From Carnsore Point to Wicklow Head, . . .	16° 25′ E.
,, Wicklow Head to Clogher Head, ...	9° 27′ W.
,, Bellagan Point, Carlingford Lough, to John's Point, Dundrum Bay, . .	48° 30′ E.
,, Donaghadee to Bruce's Castle, Rathlin Is.,	29° 11′ W.

The three last directions are not the more frequently occurring in the Bay of Dublin, but do occur. It should be noticed that the direction 48° 30′ E. is almost exactly that of the line of porphyritic rocks so markedly characterising the geology of the county Wexford.

As regards the correlation of the directions enumerated, in accordance with the theory laid down in my memoir on that subject, I should part from one or other of the Great Circles which are found to traverse Ireland. Now, as the number of coast-line Great Circles traceable on the globe has not been worked out so as to bring all the principal coast lines available into the system, I can only for the present show the connexion existing between those Great Circles which, so far, I have found to traverse Ireland, and the principal lines of direction observed by me about the Bay of Dublin.

The three Great Circles traversing Ireland, on the eastern side, so far noted, are—

The St. Lawrence Great Circle (No. 12), cuts meridian 10° W. in Lat. 52° 45′ N., at angle of 73° 45′ E. of S.

,, Caucasus Mts. Great Circle (No. 23), cuts meridian 10° W. in Lat. 52° 30′ N., at angle of 81° 20′ W. of S.

,, W. Coast of Portugal Great Circle (No. 15), cuts No. 23 G. C. in Long. 7° 2½′ W., at angle of 78° S. of W.

The Wexford coast line (16° 23′ E.) makes with the Caucasus Mountains Great Circle an angle of 70° very nearly. Taking the intersection of this Great Circle with the meridian 6° W. at 84° E. of south, this represents . . . . . 96° W. of N.

Now, the second principal direction occurring about the Bay of Dublin has been shown to be . . . } 25° 52′ W.

The difference therefore is . . . . . 70° 08′,

a sufficiently close approximation.

But the direction 25° 52′ W., and the direction 16° 23′ E. intersect at angle of . . . . . } 42° 15′.

As the angles of which these are means vary by more than 3°, it is evident that for certain values, such as 37° E. and 3° W. (magnetic), the angle of intersection would just be 40°.

The eastern boundary line of the granite mass of the Co. Wicklow is fairly represented by the direction 30° 08′ E. Now this direction makes with the St. Lawrence Great Circle, where it passes to the north of Tramore Bay, an angle of 80° very nearly.

Taking it at . . . . . 30° 08′ E.,

it intersects, in the neighbourhood of Killiney Bay, the coast line lying between Wicklow Head and Clough Head, of which the mean direction is taken at . . . . . 9° 27′ W.

The angle of intersection is therefore . . . . . 39° 35′,

which, for the reason previously cited, is a fair approximation to the theoretical angle of 40°. (This direction of 30° 08′ E. is very remarkable at Ireland's Eye.)

Nearly similar intervals occur between the directions 89° 45′ W., 50° 12′ W., and 9° 27′ W.: thus we have 39° 33′, and 40° 45′ as these intervals; while the mean of the four values, 42° 15′, 39° 35′, 39° 33′, and 40° 45′, is 40° 32′, which sufficiently represents the angular relation adopted by the theory.

It would be easy to multiply the number of cases of intersections at angles closely approximating to the values 80°, 70°, 40°; but there is a simpler and more direct proof of the correspondence of the actual lines with the theorctical: it is, that the Great Circles already mentioned correspond in a marked manner with actual lines of direction, such as main jointing, river valleys, and mountain ridges, and that from them may be derived most, if not all, the principal coast line directions. If it were possible to have the main lines of jointing carefully laid down for the whole of Ireland, it would be still more easy to multiply cases of intersection at the angles indicated, since it is fair to presume that the conclusions to be drawn from their correlation with the coast lines, and the Great Circles already cited, would not be less in accordance with the theory than those arrived at for the neighbourhood of the Bay of Dublin.

L.—On the Correlation of the Lines of Faulting of the Palamow Coal-Field District, Northern India, with the neighbouring Coast Lines. By J. P. O'Reilly, C.E., Professor of Mining and Mineralogy, Royal College of Science, Ireland.

[Read, April 12, 1880.]

Having received from Mr. Valentine Ball, of the Geological Survey of India, copies of his memoirs on the coal-fields of the Palamow district, Bengal Presidency, to which are annexed detailed maps illustrative of the geological characteristics of this district, I was led to examine the very remarkable lines of faulting which these maps present, relatively to their angular correlation with the coast line Great Circles passing through or near this district.

I considered this an excellent occasion of applying the theory of correlation of lines of direction submitted to the Academy in June, 1879, since I could have but little previous knowledge of the district on the one hand; and, on the other, the length and straightness of the lines of faulting are so remarkable, that their concordance with the theory should, so far, be a strong proof in its favour. The maps are to a scale of one inch to the mile, and therefore sufficiently large to show details with clearness.

The only great circle, of those originally traced by me on the globe, which I find to intersect the district, is that which I call the *Beluchistan East and West Coast-line Great Circle*, or, as I shall call it, the *Beluchistan Coast-line*. On the globe it cuts the meridian of 90° E. in latitude 23° 45′ N., at an angle of about 84° 31′ W. of N. This I have transferred to the maps, or rather parallels to this direction. I have further traced thereon parallels to a line of direction making, with the eastern Ghats coast-line of India great circle, an angle of 40°. Its direction differs from that of the Beluchistan coast line great circle by about 4°, that is, it would cut the meridian 90° E. at about 88°–89° W. of N. For convenience I shall term it "*The 88° W. of N. Line.*" I might have introduced other great circles or parallels to them, but the most direct proof and the simplest is the best, and I therefore confine my examination to the angular relations between the lines of faulting presented by the maps and these two principal lines of direction.

There are two 1-inch scale maps, the one of the Hutar coal-field, the other of the Auninga coal-field.

Taking the first, on which I have traced parallels to the Beluchistan coast great circle, and to the 88° W. of N. line, I find the following angular relation for the lines of faulting, and other principal lines :—

I.—A line drawn at 70° with the Beluchistan coast-line great circle, and passing through Murwaie Kullan, defines the eastern side of the coal-field.

II.—A line drawn at 40° with this gives very distinctly the northern boundary of the coal-field, over an extent of sixteen miles.

III.—A line drawn at 40° with the Beluchistan coast-line great circle (from W. to E.), and passing near Hurtah, in the north of the map, gives the direction of the mountain chain passing near this point.

IV.—The line at 30° with this, and consequently running nearly due east and west, gives the direction of certain of the sets of joints indicated in the southern part of the map, as also the southern boundary of the Mahadeva Rocks, marked Bitwa.

Taking now the second direction, that at 40°, with the eastern coast-line great circle, or as I termed it, the 88° W. of N. line:—

V.—A parallel to it gives a well-marked direction of jointing passing near Tataha, and running nearly east and west. The coincidence over the principal portion is distinct.

VI.—In the north of the coal-field this direction corresponds with that of certain of the Trap dykes marked thereat.

The line of jointing running N. N.W. and S. S. E., by the Munga Hills, I do not see how to correlate distinctly with either of the above-mentioned principal directions, that is to say, to within four or five degrees.

VII.—Taking the map of the Aurunga coal-field, and tracing on it the two directions already employed (that is, the Beluchistan coast-line great circle, and the 88° W. of N. line), there is immediately obtained the direction of the very marked jointing which runs from Rukhaut, in the south-east, to Obur, in the east centre, *an extent of eleven miles*. This line is slightly inflected, and presents, as traced on the map, two directions—the one concords with the line at 40° with the Beluchistan coast great circle, and the other with the line making the same angle with the direction 88° W. of N.

VIII.—The two main lines of direction (Beluchistan coast and 88° W. of N.) give very distinctly parts of the east and west line of jointing, which runs from Rampur to Tuppah.

IX.—They also define the system of jointing with hot springs, which runs east and west between Jorcesuklowa and Punkra, towards the northern limit of the coal-field, the length between the extreme points being nine miles.

X.—The system of jointing running N.W. by W., from Tuppah to Putkee (eight miles), can be easily correlated with the two main lines of direction by the intermediary of the angle of 80°.

XI. and XII.—A line drawn at 70° with the Beluchistan coast line great circle gives the direction of the jointing or bedding of the patch of limestone occurring in the north-east of the field; while the well-marked joint or fault crossing the direction of these limestones, from E.N.E. to W.S.W., makes with the direction of the jointing which runs from Putkee to Tuppah an angle of 40°.

The jointing which runs east and west, north of Tuppah, and its parallel about one mile to the south of it, do not give any direct and precise angular relation with either of the two principal directions already mentioned.

A few subordinate directions can also be correlated with those directions, as shown on the map, but it is not necessary to insist on them.

It will thus be seen, that at least twelve different lines of direction of jointing can be distinctly correlated with the two principal lines employed—viz., the Beluchistan coast line, and the line which makes 40° with the east coast of India great circle—by simple angular relations.

There are a few main joints which are not so correlated, because the angular relations which might be established would show differences of 4° to 5° with the theoretical values admitted: this so far goes to show how distinctly the twelve other lines do concord with the theoretical directions, and, therefore, so far go to support the general theory of correlation submitted by me to the Royal Irish Academy.

LI.—PRELIMINARY REPORT ON SOME NEW ORGANIC NITROPRUSSIDES.

By EDMUND W. DAVY, A. M., M. D., M. R. I. A., Professor of Forensic Medicine, Royal College of Surgeons, Ireland, etc.

[Read, June 14, 1880.]

THE Nitroprussides, or Nitroferricyanides, a class of salts obtained by the action of nitric acid on the soluble ferro- or ferricyanides, which were first studied by Dr. Lyon Playfair, have not received on the part of chemists the attention that might have been expected from the interesting properties possessed by those compounds; and though it is now over thirty years since they were first investigated, still comparatively little has been added to our knowledge of these salts beyond what was ascertained by their original investigator, who described in his classic researches, very fully, the principal characters of nitroprussic acid, and of some of its more important metallic salts.

As the organic combinations of that acid have received scarcely any attention, and as I thought a field for investigation was therefore open in this direction, I applied last year for a small sum out of the parliamentary grant (given to the Academy for the encouragement of scientific research) to aid me in the necessary expenses attendant on such an inquiry.

The vegetable alkaloids being as a class the most interesting and important organic bases that we are acquainted with, I naturally directed my attention to them in the first place; and I would now beg leave to lay before the Academy, as a preliminary report on the organic nitroprussides, the facts I have already ascertained respecting the combinations of nitroprussic acid with some of the more important of those substances, which, I should hope, may prove to be of some practical value, as adding to the distinctive characters of the vegetable alkaloids, and thus furnishing some additional means for the detection and separation of those bases under different circumstances. I shall commence by making a few remarks on these salts in general, and afterwards describe some of the more important of them separately in detail. I have ascertained that nitroprussic acid, the composition of which is represented by the formula $H_2(NO)FeCy_5$, is capable of forming compounds with the different vegetable alkaloids or bases. These combinations, for the most part, I find to be very sparingly soluble in water; and, when they are such, they may be readily obtained by treating any of their soluble salts with a solution of sodium nitroprusside, when the alkaloid will be precipitated in union with nitroprussic acid, producing sometimes a very characteristic deposit. On being so formed, the salt will in some cases, as in those of strychnine and brucine, exhibit itself from the first as a more or less crystalline precipitate; but in many instances, if the precipitated nitroprusside is examined under the microscope, it will be found to be

at first amorphous, or in the form of minute oil-like globules, which latter, on subsiding or on agitation, adhere to the sides and bottom of the vessel containing the mixture, forming a sticky resinous-looking deposit, or the particles agglutinate together into little lumps or masses of a similar character. But these deposits, on standing for a variable period, assume for the most part a more or less crystalline condition. In some cases, however, as for example in that of veratrine and cinchonidine, there appeared to be no disposition on the part of the salts to acquire a crystalline form, even after the lapse of a considerable time.

In the preparation of those nitroprussides of the alkaloids, which, owing to their slight solubility in water, may be obtained by precipitation, as already stated, using any of their soluble salts, still it will be found better in most cases to employ the alkaloid in the form of the sulphate; for this reason, that in the after-washing of the precipitated nitroprusside, to free it from the sodium salts with which it is associated, where the sulphate is used we can easily ascertain whether this has or has not been completely effected, by testing for sulphuric acid with a barium salt, a small quantity of the filtrate (the water used in washing the precipitate); and when such fails to produce any turbidity, it may be considered to be sufficiently washed and all the sodium sulphate with which it was mixed removed. But should the acetate, nitrate, or chloride have been employed, it will not be so easy to ascertain this point. As regards the employment of a chloride of the alkaloid in this case, I may observe that, as more or less of the nitroprusside of the alkaloid is always dissolved during the washing process, its presence in the filtrate interferes with the use of a silver salt for the detection of the alkaline chloride formed along with the nitroprusside when the chloride of the alkaloid was the salt employed.

Some of the alkaloids, as those of morphine and nicotine, as they form very soluble salts with nitroprussic acid, their nitroprussides cannot be obtained by precipitation, as in the case of the former alkaloids; but they can be easily made, either by directly dissolving the alkaloids in nitroprussic acid, or by treating solutions of their chlorides with silver nitroprusside, or their sulphates with a solution of barium nitroprusside, when, in the first case, the insoluble silver chloride, and in the second that of barium sulphate, is formed, either of which can be easily separated by filtration from the soluble alkaloid nitroprusside produced; which on subsequent evaporation, if the salt is crystallisable, can be obtained in a crystalline form. But as it is difficult to know the exact quantity of the barium salt which should be added to decompose completely the sulphate of the alkaloid, the use of the silver nitroprusside, with the alkaloid in the form of a chloride, is to be preferred; as owing to its being an insoluble salt, if it be added in excess it remains without contaminating the nitroprusside of the alkaloid: indeed it is better, as a general rule, that it should be so added, to ensure the complete decomposition of the chloride of the alkaloid, and such excess will be entirely removed during the filtering of the mixture, to separate the insoluble silver chloride formed in the process.

I have ascertained that nitroprussic acid forms (as might have been expected from its being a bibasic acid) two classes of salts with the alkaloids, viz., neutral and acid salts. In the first there exist two molecules of the base and one of the acid, and in the second one molecule of each.

I have also observed that some of the alkaloids—as, for example, morphine, strychnine, and brucine—seem to be capable of forming only neutral salts, whereas others—as those of quinine, cinchonine, and nicotine—form both neutral and acid salts, in combining with nitroprussic acid. I have noticed also that where the alkaloids form the two classes of salts, that in some cases the neutral salt is the most readily crystallizable, and the acid one much less so, and *vice versâ*; thus the quinine neutral salt crystallizes with great facility, whereas the acid salt does so with difficulty; on the other hand, the nicotine acid salt readily assumes the crystalline form, whereas the neutral one appears to be non-crystallizable.

In ascertaining the composition of those nitroprussides which I have discovered, some of which I shall presently describe, the mode I adopted was to dissolve a given weight of the thoroughly dried salt in water, which, in the case of the more sparingly soluble salts, it was necessary to be hot, or even boiling, for this purpose; and then, by the addition of a solution of silver nitrate, to precipitate their nitroprussic acid in the form of the insoluble nitroprusside of that metal, and from the amount of that salt so obtained to calculate the quantity of nitroprussic acid which had been combined with the alkaloid.

As to the water of crystallisation given in the case of some of the crystalline salts, its amount was determined in the following manner: The nitroprusside from which the moisture had been as far as possible removed by filtering or blotting-paper, and afterwards by exposing the salt to the air at the ordinary temperature, till it appeared to be quite dry, a given quantity of it was taken and heated in a water-bath till its weight remained constant, when the loss thus sustained was regarded as water of crystallization; but as it was difficult to ascertain whether the salt in the first instance had been quite freed from mechanical moisture, or had not lost some of its water of crystallization by the exposure to the air (as it is well known many salts will do when so treated), the amounts of such water, given in the formulæ of some of the salts to be described, represent the quantities that agree most closely with the results obtained by treating the salts in the manner just stated; but, for the reasons mentioned, those results will require to be confirmed by further research, before they can be taken as representing the true amounts of water necessary for the crystallization of those salts.

I may here further add, that the mode I adopted to determine the degree of solubility of the different salts in water, at its ordinary temperature, and at its boiling point, was to saturate water at those temperatures with the salt, and then taking a given bulk of the solution—the weight of which, of water alone, at such temperatures was known

—to evaporate it to dryness, and ascertain the weight of the residue or of the salt that had been dissolved in the given amount of water; and in order to obtain a saturated solution of the salt at the ordinary temperature (which in some cases, owing to the very slight solubility of the salt in cold water, would not be easily effected), the usual mode I adopted was to dissolve the salt in hot, or in boiling water, and to leave it to cool and stand for about twenty-four hours, so that the excess of salt dissolved by heat might re-crystallize out of the solution, which, after filtration to separate the crystals, the necessary quantity of it was taken, evaporated to dryness, and the weight of the residue determined.

I shall now proceed to describe the characters of the nitroprussides of some of the more important alkaloids. I shall commence with those which, owing to their sparing solubility in water, may be prepared by precipitation.

Strychnine Nitroprusside.

The first I shall speak of is the strychnine salt, as this is the * only organic nitroprusside, as far as I was able to ascertain, which has received some very slight attention, and concerning which some conflicting statements have appeared. I believe that Mr. John Horsley, of Cheltenham, was the first to point out that sodium nitroprusside formed a crystalline precipitate with strychnine salts, and finding that where it had been added to a mixture of that alkaloid and strong sulphuric acid, the characteristic purple reaction (which is developed by strychnine, when it is acted on by different oxidizing agents under those circumstances) was produced, he proposed it, the sodium nitroprusside, as a more delicate reagent than potassium bichromate for that purpose. But it was subsequently shown by Rogers and Neubauer that this reaction which Horsley observed was due to the nitroprusside he employed containing potassium ferricyanide, known in commerce as the red prussiate of potash—a salt which, several years ago, I myself proposed to be used in conjunction with strong sulphuric acid, as a test for strychnine; and which, according to my experiments, possesses some advantages for that purpose over the potassium bichromate, the salt which is usually employed in the detection of that alkaloid. And I mention this circumstance, as in several chemical works where my name has been quoted in connexion with this test, an error has been made in putting the ferro- instead of the ferricyanide of potassium, as the salt to be employed; for the former, which is well known under the name of the yellow prussiate of potash, has no

* Since my investigations were made, I have ascertained that Mr. Horsley, several years ago, proposed sodium nitroprusside as a test for certain alkaloids, and pointed out that when it was added to solutions of brucine, and to those of morphine, and the mixtures examined under the microscope, that characteristic crystals were produced, as well as in the case of strychnine, to which he had previously directed attention. See *The Chemical News*, vol. v. p. 355.

power whatever of developing the characteristic reaction of strychnine under the circumstances stated. But to return to the sodium nitroprusside; my experiments on that salt fully confirm the statement of those two chemists already mentioned, as to its incapability of developing the purple reaction when added to a mixture of strychnine and sulphuric acid.

I shall now describe the reaction of sodium nitroprusside on a soluble salt of strychnine, and point out some of the properties of the resulting nitroprusside of that alkaloid. When a solution of the former salt is added to one of the latter, there will be immediately formed a dull reddish-white precipitate, which, on being examined under the microscope, will be found to be in great part of a crystalline character, consisting of very fine prismatic crystals. On heating the mixture, the precipitate will dissolve; and on cooling, it will reappear in a lighter and more completely crystalline form, the crystals being arranged in a peculiar brush or fan-shaped manner, or radiating from a point in all directions. Some of this salt which had been precipitated by a solution of sodium nitroprusside, and was washed and dried in the way already described, was taken and heated in the water-bath till its weight remained constant, and the loss sustained by a given quantity was noted. The thoroughly-dried salt was then dissolved in water, and precipitated by a solution of silver nitrate, and the silver nitroprusside so formed ascertained. From these two results—viz., the amount of water lost by drying, and of silver nitroprusside obtained—agreeing most closely with the amounts which should by calculation be furnished by a salt having the formula $(C_{21}H_{22}N_2O_2)^2.H_2(NO)FeCy_5 + 3H_2O$, where two molecules of the base are combined with one of the acid, plus three atoms or molecules of water of crystallization, there can therefore be no doubt that this formula expresses the composition of the salt, at least as regards the relative proportions of the base and acid. As to the water of crystallization, there is not the same certainty, for this salt readily loses such water by exposure to the air at the ordinary temperature, and consequently it is difficult to remove the moisture without its losing at the same time more or less of the water necessary for its crystallization. Its composition shows that it is a neutral salt, and test-papers indicate the neutrality of its solutions. As to its solubility in water, I found by the means already described that it required about 847 times its weight of cold, and very nearly 66 times its weight of boiling, water for its solution.

It dissolves but slowly and in comparatively small proportion in rectified spirit, either hot or cold, and is only very slightly soluble in chloroform, and still less so in ether, and does not appear to be dissolvable by benzole.

I may observe, as regards the crystallization of this salt, that, though it usually assumes one or other of the forms already described, yet, when it very slowly crystallizes from its aqueous, or more particularly alcoholic solutions, it presents itself, at least in part, under the form

of very thin square or rectangular plates; and I may also state, that when the crystals of this salt are exposed to the air, they become more or less opaque, and present a silky reddish-white appearance. I may further add, that strychnine does not appear to be capable of forming an acid salt with nitroprussic acid.

Brucine Nitroprusside.

When a solution of sodium nitroprusside is added to a soluble salt of brucine, such as the sulphate, a dull yellow precipitate will be immediately formed: this, when examined under the microscope, will be found to be more or less crystalline; and on heating the mixture, as in the case of strychnine salt, it will dissolve completely; and on cooling it will again reappear, but in a lighter and much more crystalline form, consisting of long and slender four- or six-sided prisms, terminating in wedge-shaped ends, and when dry presents a light-yellow colour. Some of the salt obtained as just stated was washed and dried in the manner already described, and a given weight of it being taken, it lost by drying in the water bath, and yielded of silver nitroprusside, quantities of water, and of the silver salt, which agreed very closely with those which should have been furnished by a salt having the formula $(C_{23}H_{26}N_2O_4)^2.H_2(NO)FeCy_5 + 3H_2O$, in which two atoms of brucine are united to one of nitroprussic acid, and three atoms of water are combined with the salt in its crystalline form; consequently, I conclude that such is its constitution.

It is a perfectly neutral salt, which is very sparingly soluble in cold water, but dissolves in much larger quantity in hot or boiling water; and from an experiment I made, I found that the thoroughly dried salt required about 736 times its weight of cold, and only about 58 times its weight of boiling, water for its solution. It readily dissolves in rectified spirit, and is soluble to a considerable extent in chloroform and in ether, but is much more so in the former than in the latter, and it appears to be almost insoluble in benzole.

Quinine Nitroprussides.

The alkaloid quinine is capable of forming with nitroprussic acid two salts, viz. a neutral and an acid one. The first was obtained by dissolving quinine neutral sulphate in boiling water, and adding to this solution, whilst still hot, sodium nitroprusside. A solution of this latter salt, on being gradually added drop by drop to the quinine solution, at first produced no precipitate, or, if any was formed, it was immediately redissolved; but on continuing its addition, prismatic crystals began to appear, and to increase in quantity. The sodium nitroprusside was added till the mixture acquired a reddish colour from an excess of that salt; it was then suffered to cool, when a further quantity of the new salt crystallised out; this was then separated by filtration, and washed with cold distilled water, to remove the sodium sulphate formed and the excess of sodium nitroprusside;

and the washing was continued till barium chloride failed to indicate the presence of sulphuric acid in the water used in washing the salt. It was then drained and dried, first by being placed between blotting-paper, and afterwards by exposing it to the air for some time, till it appeared to be quite dry. When so prepared it had a light-reddish colour and a somewhat glistening appearance; and, on being placed under the microscope, it was found to consist of prismatic crystals, the prevailing forms of which were six-sided prisms, many of which had wedge-shaped terminations. The salt is only very slightly soluble in cold water, it requiring about 2500 times its weight of that liquid at the ordinary temperature for its solution, and this very small quantity of the salt scarcely affects its colour. It is much more soluble, however, in boiling water, of which it requires about 83 times its weight to dissolve it; and, when saturated at this temperature, it has a faint brownish colour; and its aqueous solutions are neutral to test-papers. Though it is so sparingly soluble in water, it dissolves readily in rectified spirit. From the amount of silver nitroprusside which a given weight of the thoroughly dried salt yielded, it was evident that two molecules of quinine were combined with one of nitroprussic acid, and that it was a perfectly analogous salt with the quinine neutral sulphate, and that its composition was represented by the following formula:—$(C_{20}H_{24}N_2O_2)^2.H_2(NO)FeCy_5$. As to the quantity of water this salt requires for its crystallization, I shall not venture to state; for the loss which a given weight of the air-dried salt underwent by heating in the water bath was so very trifling, I conclude that it must have lost the greater portion of its water of crystallization in its preliminary drying, and it will require further research to determine this point.

Before leaving this salt I may add that, when to a cold saturated aqueous solution of quinine neutral sulphate, sodium nitroprusside is gradually added, drop by drop, it produces a reddish-white precipitate, which at first re-dissolves, but, on continuing the addition of the nitroprusside, it ceases to disappear, and leaves the mixture turbid; on its standing, however, for a short time, the precipitate assumes a somewhat crystalline appearance, and after a further interval it subsides, forming a somewhat granular deposit, which, on being examined under the microscope, is found to consist of short prismatic crystals, radiating from a point in a stellate form; but the salt, whether precipitated from a hot or cold solution, appears to be the same compound.

The quinine acid nitroprusside was obtained by the following process:—Some quinine neutral sulphate having been dissolved in water, by the addition of the least possible amount of diluted sulphuric acid; to this solution was added gradually sodium nitroprusside. This produced at first a reddish-white precipitate, which, on examination under the microscope, was found to consist of minute, oil-like globules; these, after a short time, aggregated together and subsided, adhering to the sides and bottom of the glass containing the mixture, in the form of a very sticky and resinous-like deposit; but this, after

remaining some time longer, became somewhat opaque, and presented a more or less crystalline appearance, which, when examined under the microscope, was found to consist of masses of minute, flattened, oblique prismatic crystals, the forms of which, however, were very different from those of the neutral salt. Some of this nitroprusside, which had assumed the crystalline condition, was washed with a little distilled water, and dried, and the amount of silver nitroprusside which a given weight would furnish ascertained. This was found to correspond almost exactly with the quantity of silver nitroprusside which a salt of the following composition should yield:—$C_{20}H_{24}N_2O_2.H_2(NO)FeCy_5$. It has an acid reaction, and is much more soluble in water than the neutral salt, requiring only about 107 times its weight at the ordinary temperature for its solution, and when so dissolved it gives to the water a reddish-brown colour. It also readily dissolves in rectified spirit, especially on the application of heat. In its composition and properties it is, therefore, a perfectly analogous salt to the quinine acid sulphate. This salt, like the neutral one, on exposure to the air, loses more or less of its water of crystallization.

Cinchonine Nitroprussides.

Cinchonine, like quinine, forms two salts with nitroprussic acid. The neutral one was obtained from cinchonine neutral sulphate, as in the case of the quinine salt, only that in this instance, owing to its greater solubility, a cold saturated solution was employed instead of a hot one. On adding sodium nitroprusside to such a solution of cinchonine, an immediate reddish-white precipitate was formed, which, when examined under the microscope, presented the appearance of minute oil-like globules: these, on agitation, agglutinated into lumps, which stuck to the sides and bottom of the glass in a resinous form, and acquired a darker reddish colour. These masses, on standing till the next day, became crystalline, and small reddish-brown crystals, which were peculiar compound modifications of the cube and octahedron, were found floating on the surface of the liquid and adhering to the sides of the glass containing the mixture. This salt, after draining and washing with a little distilled water, was dried, and the amount of silver nitroprusside which a given quantity would yield ascertained: this was found to agree very closely with that which should be furnished by a salt having the following formula:—$(C_{20}H_{24}N_2O)^2.H_2(NO)FeCy_5$. It is therefore a neutral salt, agreeing in its constitution with the corresponding quinine salt. This salt is soluble in about 192 times its weight of cold, and in about 35 times its weight of boiling, water, and it readily dissolves even in cold rectified spirit. When this neutral salt was dissolved in nitroprussic acid it yielded an acid crystallizable salt, which, no doubt, has the composition of the corresponding quinine acid salt.

Quinidine and Cinchonidine Nitroprussides.

Quinidine and cinchonidine, two bases which are isomeric or of the same percentage composition with quinine and cinchonine (and are obtained from quinidine—a resinous matter produced in the preparation of quinine), form, with nitroprussic acid, as might be expected, neutral and acid salts corresponding with those of quinine and cinchonine. The quinidine neutral salt is thrown down from the first in great part as a crystalline precipitate, when a solution of the neutral sulphate of that base is treated with one of sodium nitroprusside. Its crystals are prismatic, and of a very light brown colour. This salt requires about 105 times its weight of cold, and about 50 times of boiling, water for its solution; and it is readily soluble in rectified spirits. Its solutions are neutral, and there can be no doubt that its composition is similar to the quinine neutral salt where two molecules of the base are united with one of the acid.

The cinchonidine neutral salt, which is obtained by the same means from the neutral sulphate of that base, is precipitated in the form of minute oil-like globules, which on subsiding adhere together, forming a sticky, more or less transparent, brown deposit, which exhibits no disposition to crystallise even after standing for a considerable time. This, on exposure to the air, hardens, becoming at the same time very brittle and resinous in its appearance. This nitroprusside requires about 217 times its weight of cold, and about 21 times of boiling, water for its solution, and it dissolves readily in rectified spirit. This salt being neutral in its reaction, there can be no doubt that its constitution is similar to the corresponding cinchonine salt, where two molecules of the base are combined with one of the acid. The apparent absence of any disposition on the part of this nitroprusside to assume a crystalline condition, affords a distinctive character between this and the corresponding cinchonine salt; for though the latter is precipitated at first like the former, in minute oil-like globules, and forms an apparently similar sticky, transparent, brownish deposit, still, on standing for a variable period of some hours, it becomes highly crystalline, furnishing very characteristic crystals, as already stated, some of which may sometimes be seen floating on the surface of the supernatant liquid, or adhering to the sides of the vessel in which it is contained. This salt, as well as the neutral quinidine nitroprusside, dissolves readily in nitroprussic acid, and they both thus form crystallizable acid salts similar to those in the case of quinine and cinchonine; but their further properties I have not yet been able to determine.

Veratrine Nitroprusside.

Veratrine, the active principle of the white hellebore, which is a very powerful poison, forms with nitroprussic acid a neutral salt, which may be readily obtained by precipitating its sulphate with sodium nitroprusside, when it presents itself as a cream-coloured or

almost white precipitate, which is amorphous, and its particles did not agglutinate together like some of the other nitroprussides, which do not assume a crystalline form when so precipitated. It was very slow in subsiding, though it was easily filtered and washed, the filtrate from the first passing through clear: after washing, till it gave scarcely a trace of sulphuric acid, it was dried and examined. In this state it is almost white, and differs little in its appearance from veratrine itself. It is sparingly soluble in both cold and hot water, requiring about 416 times its weight of water at the ordinary temperature, and about 215 at the boiling point, for its solution. This nitroprusside, unlike most of those of the other alkaloids, does not appear to have any disposition to form a crystalline salt, even after long standing. I have not yet been able to ascertain the proportion of base and of acid that it contains; but there can be little doubt that it consists of two molecules of the base combined with one of the acid, as in the case of the neutral salts of the other alkaloids. It is very soluble in rectified spirit, both cold and hot; and in ether it dissolves to a considerable extent, whilst in chloroform its solubility is much less.

From the experiments I made, it does not appear that veratrine is capable of forming an acid salt with nitroprussic acid.

Morphine Nitroprusside.

I shall now describe a few of the nitroprussides of the alkaloids which form very soluble salts, and therefore cannot be obtained by precipitation, as those already noticed.

The very important alkaloid morphine, the chief active principle of opium, forms a readily crystallizable neutral salt with nitroprussic acid. It was obtained by simply dissolving, with the assistance of a gentle heat, morphine[1] in nitroprussic acid, till a perfectly neutral solution was obtained. This, which was of a reddish-brown colour, being filtered, and the filtrate somewhat concentrated by evaporation on the water-bath, began to furnish prismatic crystals; and in order to obtain these of larger size and more perfect form, the solution was

[1] The nitroprussic acid used in forming this and other salts was easily prepared by digesting for some days, with occasional agitation, silver nitroprusside in diluted hydrochloric acid, contained in a well-stopped bottle; when the nitroprussic acid and silver chloride are formed by double decomposition, and the former may be separated from the latter by filtering the mixture. In preparing thus this acid, it is necessary to employ an excess of silver nitroprusside to ensure the complete removal of the hydrochloric acid employed. That such is the case may be ascertained by collecting some of the silver chloride, and this being well washed on a filter with distilled water till the filtrate becomes colourless; if then, after the addition of a few drops of diluted hydrochloric acid to the chloride, the water used in washing it again acquires a reddish colour, it is a proof that there was some silver nitroprusside in excess over that necessary to remove the whole of the hydrochloric acid. Indeed, if the silver chloride formed, after being well washed, has a reddish colour, it indicates the same fact.

then placed under a bell-glass along with a vessel of sulphuric acid, and the air exhausted, by which the further evaporation was readily effected, and when the liquid portion was thus nearly all removed, the crystals were drained, placed on filtering paper, and afterwards exposed to the air for some hours; and when they appeared to be thoroughly dried, the salt was taken for examination. The crystals so prepared were of a reddish-brown colour, and their form that of four-sided prisms, some of which terminated in wedge-shaped ends, but most of them abruptly, as if broken across. A given quantity of the salt was then taken, and heated in the water-bath till its weight became constant: by this treatment the crystals became more or less opaque and friable, so that they were easily reduced to powder, though they retained their external form. I found that the amount of water lost in this way, and the quantity of silver nitroprusside yielded by a given weight of the thoroughly-dried salt, agreed most closely with the quantities of water and of silver nitroprusside which should be furnished by calculation, from a salt of morphine having the formula $(C_{17}H_{19}NO_3)^2$, $H_2(NO)FeCy_5 + H_2O$, where two molecules of the base were combined with one of the acid, plus one atom of water of crystallization. It is consequently a neutral salt in its constitution, and its solutions also indicate its neutrality. The salt appears to undergo no change by exposure to the air, its crystals having retained their form and appearance after long exposure to its action. This nitroprusside dissolves slowly in cold water, but readily in hot; and, from an experiment I made, I ascertained that it required about 112 times its weight of the former for its solution. It dissolves slowly in rectified spirit, especially at the ordinary temperature; and is only very slightly soluble in ether and in chloroform. Before leaving this salt I should observe that it may also be readily obtained by treating a solution of morphine chloride with an excess of silver nitroprusside, when the morphine nitroprusside and the silver chloride will be produced, and the former, which remains in solution, is easily removed from the latter, as well as from the excess of silver nitroprusside that may be present, by filtration.

I may further add that, from some experiments I made, it does not appear that nitroprussic acid is capable of forming an acid salt with morphine.

Nicotine Nitroprussides.

Nicotine (the active principle of tobacco, which is one of the most deadly of our poisons, and, like prussic acid, will destroy life with great rapidity when taken even in very small doses) is capable, I find, of forming two salts with nitroprussic acid, viz., a neutral and an acid one. As the neutral salt does not appear to be crystallizable, whilst the acid one is readily so, the latter possesses the most interest, and consequently was the one I chiefly studied.

It may be easily obtained by adding to an aqueous solution of nicotine nitroprussic acid till the mixture has a strong acid reaction

and the odour of nicotine almost disappears; this solution on evaporation will furnish long prismatic, reddish-brown crystals, the prevailing forms of which are six-sided prisms with truncated ends. These crystals are permanent in the air—at least they appeared to undergo no change by exposure to its influence for a considerable time. This salt is readily soluble in both cold and hot water, and of the former it requires only about 17 times its weight for its solution, and when thus fully saturated with the salt the water acquires a deep reddish-brown colour. It is also soluble in rectified spirit, though rather sparingly so, at the ordinary temperature; but on the application of heat it dissolves in it readily and in considerable quantity, giving to the solution a dark reddish-brown colour, very similar in its appearance to the saturated aqueous solution, and which on cooling yields a considerable proportion of the salt in the crystalline form, and consequently spirit may with advantage be employed in its preparation and purification. It is very slightly soluble in ether, and is almost insoluble in chloroform.

A given weight of the salt, which had been dried by means of blotting-paper and by subsequent exposure to the air, was heated in the water-bath till it ceased to vary in weight, when the crystals acquired a dull appearance from the loss of their water of crystallization; and the amount of such loss, and the quantity of silver nitroprusside that the dried salt yielded, agreed very closely with the quantities which should be furnished by a salt having the formula $C_{10}H_{14}N_2$, $H_2(NO)FeCy_5 + 2H_2O$, where one molecule of nicotine was combined with one of nitroprussic acid, plus two atoms of water of crystallization. It is therefore by its constitution an acid salt, and its solutions possess a strong acid reaction, and the salt itself has no odour of nicotine.

I may further observe that in preparing this salt, if sufficient nitroprussic acid has not been added in the first instance to convert the whole of the nicotine into the acid salt, some of the neutral one will remain after the separation of the crystals of the former salt, and on the further addition of the acid a fresh crop of crystals of the acid nitroprusside will be obtained. But a much better way of forming this and other acid nitroprussides of the alkaloids would be to take two equal portions of nitroprussic acid, and, having neutralized one completely with the alkaloid, to add to it the other, when at once the desired end would be obtained.

Nicotine forms a neutral salt also with nitroprussic acid; for when that acid is carefully added to an aqueous solution of that base, a neutral mixture may be obtained, which, on evaporation under a bell-glass *in vacuo* with sulphuric acid, yields a dark reddish-brown syrupy residue, exhibiting no disposition to crystallize, and evolving a strong odour of nicotine, and on further drying forms an almost black resinous-looking mass.

This dissolves readily in water, forming a dark-brown neutral solution, which on heating gives off a strong odour of nicotine, and

gradually becomes more and more acid in its reaction from the formation of a small quantity of the acid salt. And this neutral compound will, on the addition of more nitroprussic acid, furnish crystals of the acid salt. Though I have not yet determined the proportions of base and acid in this nitroprusside, there can be no doubt that there are two molecules of the base combined with one of the acid, as in the case of the neutral salts of the other alkaloids. And I may further add, that the same neutral salt was likewise obtained by the action of silver nitroprusside on a neutral solution of nicotine chloride.

Though the foregoing observations, as I am fully aware, leave much yet to be done in the direction I have been pursuing, still I thought it better, before the close of the session, to make this preliminary report, embodying the results I have already obtained in investigating some of the organic salts of nitroprussic acid. But I trust that before long I may be able to extend my observations, not only as regards the alkaloids, but to other organic bases, when I hope to lay my results before this Academy in a more complete and perfect form.

LII.—Preliminary Notice of a Memoir on Rock-jointing, in its relation to Phenomena in Physical Geography and Physical Geology. By Professor William King, Sc.D., &c. (Abstract by the Author.)

[Read, June 18, 1880.]

The author in the beginning introduces the principal conclusions (of which there are six) which he has arrived at in his "Report" on the Jointing of Rocks, &c., published in the *Transactions of the Royal Irish Academy*, 1875, Vol. xxv.; after which he notices what has lately been published on the subject by Daubrée and Sorby, whose remarks, he maintains, are confirmatory of his main conclusions.

According to the author, jointing is a physical phenomenon, which, constituting lines or zones of weakness in the earth's crust, has permitted subterranean disturbances, often accompanied by igneous upbursts, to follow the courses of these zones. Such disturbances have greatly affected rocks possessed of jointing, compressing them at right angles to the course of an axis of disturbance, and bringing the planes of jointing into immediate contact; thus developing slaty cleavage. The same agencies, besides producing enormous dislocations or faults, have, by their transgressive action, flexured rocks into mountain chains, and intervening valleys into parallelism with an axis of disturbance.

Although agencies of the kind have often obliterated jointing, the writer assumes that cleavage planes represent it; also that the strike of these planes indicates the course or direction pursued by the obliterated jointing, and consequently the system to which this divisional structure belonged.

He, moreover, regards the coast-lines of continents as a correlative phenomenon; taking these features to be defined by the great submarine slopes which rapidly descend into the abysses of the oceans.

This last point brings the author in contact with Dana, who contends that the earth's continents have always been continents, or, as the writer puts it, that the present continents, in the main, have been from the earliest geological periods greatly elevated regions, separated by enormously deep depressions. So far, there is some agreement between both authors. Dana, however, contends that our continents have been produced by regional up-bendings and down-bendings of the earth's crust, the former giving rise to continental masses, and the latter to great ocean basins; whereas the writer, although accepting the pre-Cambrian antiquity of the main surface features of the *earth's crust*, maintains that our continental coast-lines are in correlation with enormous faults, which have thrown down the rocks on one side of a dislocation thousands of feet below their corresponding masses on the other side. He furthermore maintains that the general direction of any given continental coast-line has been determined by some system or section of jointing.

There are two systems of the kind—one *meridional*, and the other *equatorial*, depending on the maximum frequency of the joints in certain points of the compass. The first, especially, is divisible into two sections—east-of-north, and west-of-north : a third section, not so strongly developed, may be added, which, running north and south, that is, between the others, may be called medio-meridional. The equatorial system, in general imperfectly developed, may also be divided into two or more sections. As the earth's continents have their chief coast-lines running in directions corresponding to the two principal meridional sections, his contention is, that their east coast-line belongs to, and has been aligned, by the east-of-north meridional jointing; also that their west coast-line stands in corresponding relation to the west-of-north section.

Contending that jointing, slaty cleavage, great lines of faulting, continental coast-lines, and mountain chains are correlative phenomena, he feels himself powerfully sustained, not only by the parallelism between the United States coast and the Appalachian ridges, but equally by the corresponding parallelism of enormous faults—some with a down-throw of thousands of feet—which characterise this mountain system. One of the faults is known to stretch from Quebec to New Jersey!

The disturbances which developed the "great feature-lines" of our globe seem to have been in operation in pre-Cambrian periods. Evidences have been discovered in the Rocky Mountains, by Clarence King, of a mountain, or regional mass, defined in one tract by a nearly vertical cliff, which, with an altitude of 30,000 feet, was presumably in existence before the earliest palæozoic deposits were formed.

The agent which gave an east-of-north trend to the west coast of Europe similarly affected much of the north-west coast of Africa; and seemingly it struck obliquely across the equatorial section of the Atlantic, re-appearing at Cape St. Roque, and proceeding onward, along the mountainous sea-board of Brazil, to the La Plata. Enormous as undoubtedly is this extent of coast-line formation, it is surpassed by what is presented by the west coasts of the two Americas and the east coast of Asia; obviously the former, with its parallel mountain ranges, being in genetic relation with the west-of-north and median sections of meridional jointing, and the latter with the east-of-north section.

Attention is next directed to the great inland ranges constituting the Alps and the Himalayas. Both mountain masses have been more or less affected by forces exerted in directions belonging to the two principal sections of meridional jointing; but in both cases the phenomenon has been greatly swayed by movements presumably acting under the influence of the equatorial system.

The disturbances which developed High Asia—a vast continental mass within a continent stretching from India to the tundras of the Taimyr peninsula, in Asiatic Siberia—have ridged it up trans-

versely into mountain chains, with intervening desert platforms. Its southern extremity is formed by the Himalayan and other ridges; their general level, from 20,000 to 24,000 feet in altitude, culminating in still loftier peaks, some not far short of 30,000 feet. All the transverse ridges, in a great portion of their length, have an east and west course; while their terminations generally curve northwards.

The development of High Asia is a vastly complex phenomenon, presumably resulting from disturbances which have been directed along different zones of weakness. The zone in correlation with equatorial jointing seems to have been the medium through which the transverse ridges and their individual igneous axis were upheaved; while those referrible to the two principal sections of meridional jointing may have similarly influenced their terminations on both sides of this huge plateau, especially in the region east of it; where mountain ranges, coast-lines, and off-lying islands all coincide in their strike with the east-of-north meridional jointing. The lofty parallel ridges east of Burmah, in being medio-meridional, are so far in conformity with the last-mentioned features. This abstract will scarcely permit of any reference being made to the equatorial extensions from the Pamir through Western Asia, &c.

Respecting another prominent feature of our continents, it is assumed that the east-of-north and the west-of-north sections of meridional jointing have primarily marked out the sides of the triangle, under which form these great land masses are for the most part presented; while the base of the triangle is ascribed to equatorial jointing. But it is not yet clear why the base of the triangle faces the north, and its apex points to the south. The writer thinks the solution lies in the fact that the greatest elevated land masses characterise the Northern Hemisphere and equatorial regions; a disposition which would cause a greater width of elevated land to lie within the basal area of the triangle than at the apex.

The question next suggests itself, arising from a consideration of all the phenomena noticed in the memoir,—if the original elevated plateaus have always existed as masses, having an elevation far above the bottom of the great intervening depressions (oceans)—how have they become covered up with oceanic sediments thousands of feet in thickness, and representing successive geological periods? In this connexion it is argued that elevations of rock-masses are of two kinds:—one due to stratial disturbances, which for the most part have been exerted horizontally, or approximately so; and the other to vertical movements, extending over wide geographical areas. The author's early attention was called to the latter class of movements by the beautifully developed series of terraces in the Burren of Clare, reaching to the height of nearly 1200 feet. He ascribes this particular instance to a slow upheaval of the district above the sea, the surface of each terrace representing the bottom of a shore-line—a plane of marine denudation, and an apparent stoppage in the upheaval. The terraces of

Lochaber have been examined by him, with the result of his having become convinced that they are ancient sea-margins: 1495 feet is the height usually stated of these terraces; but he detected on the flanks of Ben Nevis and the opposite mountains the like features, which must reach to an altitude of between 2000 and 3000 feet. Besides the raised shell-beaches standing at a comparatively low level on the coasts of Norway, terraces have been lately observed and described by Dawkins, which occur on the Dovrefelds, at the heights of from 2000 to 3100 feet. Darwin's account of the remarkable examples that occur in Patagonia, up to the height of 1300 feet, leaves no doubt on the present writer's mind that they have been formed by the action of the sea. Hector has described vast terraces on both the Atlantic and Pacific slopes of the Rocky Mountains, stretching from Athabasca River to Mexico, and rising one above another to heights ranging from 3500 to 4500 feet above the level of the sea. The late Daniel Sharpe made known the occurrence of lines of erosion on the inner and outer flanks of the Swiss Alps, at about 4800, 7500, and 9000 feet above the sea. And, to finish what could be made a much longer list, Rudolph Griesbach has described terraces in Natal lying at heights of about 1000, 2300, and 5000 feet: it would also appear that these correspond with certain of the plateaus common in the Cape Colony. In short, it may be safely stated that marine terraces are to be seen in every region of the globe.

In the deep valleys of the lofty southern buttress—Great range of Thibet—terraces ascend to the height of 16,000 feet; but as these may have been formed along the shores of elevated lakes, such as are now in Ladak and adjacent countries, it would be unsafe to classify them with the marine representatives that have been noticed.

The writer, nevertheless, maintains that a number of geological evidences afforded by the vast area last noticed, combined with the proofs already brought forward, establish the conclusion that vertical movements, equal to hemispheres in extent, have affected not only High Asia, but the entirety of the earth's surface; elevating continents, including their mountains and plateaus, at the same time uplifting the bed of the intervening oceans, thousands of feet above their present level; or plunging them as deeply in the opposite direction.

Without denying that the level of the sea may have undergone great fluctuations at intervals during past geological time, and that such changes may have participated, to an extent far beyond what physicists and hydrographers are at present disposed to admit, in effecting phenomena which, for convenience sake, he collectively ascribes to vertical movements in the earth's crust,—or, without offering any opinion respecting the hypotheses suggested by Babbage, Herschel, and others, as to the cause of phenomena of elevation,—it does not appear improbable to the author that vertical movements have by slow degrees, and during a series of vast chronological terms, alternately elevated and depressed opposite areas corresponding in extent with a hemispherical division of the globe.

To illustrate this view, let it be assumed that one of our hemispheres, having attained its maximum elevation, is next to undergo subsidence. During this elevated period the *land surfaces* of moderate height would be in what may be termed the *first* stage of depositional action, viz., the formation of subærial, fresh-water, and estuarine deposits: in the *second* stage they would be under marine conditions, producing littoral and deepish-water conglomeratic, arenaceous, argillaceous, and calcareous beds: in the *third* stage they would be under pelasgic conditions, developing limestones, argillites, and siliceous rocks. Next, elevation having supervened, the *fourth* stage would be a repetition of the second, yielding comparatively shallow-water marine deposits, and terminating by passing into the first stage. Thus would our continents, notwithstanding their being at present at an average height of a few thousand feet above the sea-level, become over-laid by vast deposits of all kinds—those of any given stage being the equivalent of one of the formations, usually four, which constitute a geological system of rocks (take, for example, the Carboniferous System); and, moreover, the whole agreeing with the formations of a system in their usual order of superposition.

A few points must be briefly added. It is not assumed that all great vertical movements have proceeded in the invariable course, and to the extent, vertical, or areal, as above illustrated; nor that they were unaccompanied by minor ups and downs. The hemisphere opposite to the one given as an illustration would be undergoing counter vertical movements. As to the deposits which were thrown down over the abysses of the oceans (Atlantic and Pacific) when the continents were under pelasgic conditions, it is admitted they involve some questions difficult to answer, whether considered in connexion with Dana's hypothesis, or the author's.

Obviously great recurrent climatal changes would result from these elevations and depressions; severe glacial conditions accompanying the one, and the replacement of the latter by genial ameliorations consequent on the other.

The consideration of these points gives rise to the question, often debated;—how has it happened that after the Pliocene period climatal conditions prevailed which converted a great portion of Europe and North America (there are grounds for excepting Northern Asia) into ice-covered regions; and that during the Miocene, or probably some portion of the Pliocene period, areas lying frem 10° to 20° of the North Pole, as it appears to some geologists, have enjoyed a climate approaching in genialness that of the south of Europe at the present day. The writer, rejecting all the hypotheses that have been offered in explanation of these climatal interchanges, maintains that they are mainly due to the afore-mentioned vertical movements.

Confining himself to the climatal conditions which characterised Grinnell Land, Spitzbergen, and other Arctic areas during the Miocene period, as indicated by their plant-remains, he suggests that these and adjacent areas stood at a somewhat lower level relatively to the sea than at present; and formed an archipelago, freely permitting

currents, with a temperature slightly more elevated than that of the gulf-stream where it now strikes the west coast of Ireland, to bathe the coasts of its islands. Climatal amenities now prevail in Northern Scandinavia, the Kara Sea, and the Taimyr peninsula of Asiatic Russia: the last place, the most northern continental land of the globe, now supports an exuberant forest vegetation in a much higher parallel than anywhere else within the Arctic circle, and only about 16° short of the North Pole: while the fact is evidently due to the presence of warm water carried by ocean currents, and by rivers (as the Yeneissi) from the south. Northern Siberia, in direct communication with southern lakes and ocean streams, charged with warm water, and in the condition of an archipelago;—why may not its great forest belt be extended up to Spitzbergen and Franz Joseph Land—to parallels corresponding with those in Grinnell Land, which formerly supported the growth of a vegetation approximately similar in some respects to that now characteristic of Northern Italy and the Southern States of North America?

As to the long winter-night of darkness, and the long summer-day of sunlight, he is satisfied from adducible evidences, that, other things being favourable, such conditions would rather favour than impede vegetable growth.

The memoir concludes with remarks on igneous disturbances. Admitting the existence of a number which may be included in the equatorial system of jointing, it is stated that disturbances of the kind are for the most part limited to certain of the meridional zones of weakness. As is well known, a most important series of volcanoes characterises the west coasts of the two Americas, and a similar series lies off the east coast of Asia; belonging, in the author's opinion, one to the west-of-north, and the other to the east-of-north section: both series become united in Behring Sea. Other writers, by connecting the equatorial series of volcanoes north of Australia with the above two, have constructed a "circle of fire," but, according to the present writer, with far too limited a range. He contends that the two meridional series (by pursuing a direct course, so as to embrace the Cocos Island, St. Paul's, Kerguelan's Land, Enderby's Land, thence curving to Trinity Land, passing on to the South Shetlands, and through Fuejia into the Patagonian Andes), form but one—a great volcanic girdle; which may be said to stretch without interruption around the world, traversing the Arctic regions a few degrees east of the North Pole, and intersecting the Antarctic circle at a corresponding distance west of the South Pole; thus dividing the crust of the globe along its greatest zones of weakness into two nearly equal halves.

As to reflections which may naturally arise in connexion with the last subject, it may be remarked that the writer is, scientifically, too much of a teleoptomist, too extravagant a timist, and too little of a catastrophist, to entertain any involving serious or disquieting apprehensions.

LIII.—On some Anomalous Structures in Human Anatomy. By J. F. Knott, F.R.C.S.I., L.K.Q.C.P.I., Demonstrator of Anatomy, Royal College of Surgeons, Ireland.

[Read, December 8, 1879.]

The anomalous structure to which I have the honour of calling the attention of the Members of the Royal Irish Academy was discovered in the dissecting-room of the School of the Royal College of Surgeons.

I had been assisting in the dissection of the spinal cord and the ligaments of the vertebral column of the subject on which it was found. Those of the two upper vertebræ were left till the last, as I

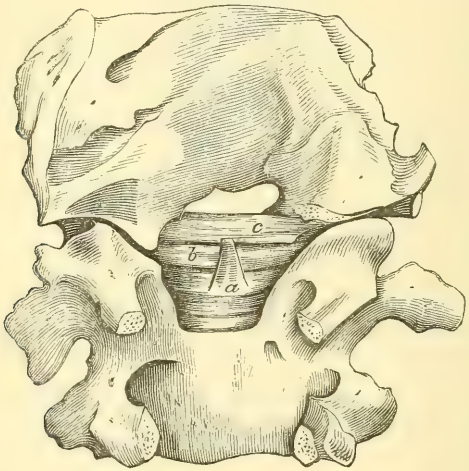

Fig. 1 represents the parts, and gives a good idea of the connexion of the ligament in question with the upper margin of the transverse ligament—*a*, superior appendix of cruciform; *b*, upper part of transverse ligament; *c*, ligamentum transversale occipitale.

had already intended to examine them with special attention. The posterior part of the occipital bone had been removed in the course of the dissection, as well as the laminæ of all the vertebræ. The *posterior common ligament* of the spine had been examined, and its prolongation into the cranium through the foramen magnum traced along the upper surface of the *clivus* as far as the upper margin of the *dorsum sellæ* and the posterior clinoid processes. After the removal of this structure the *apparatus ligamentosus* was defined, but no peculiarity was observed to exist either in its structure or attachments. This having been in its turn taken away, and the subjacent bursa examined, I proceeded to define the outlines of the cruciform

ligament. I now observed what I at first took for a disproportionate increase in the depth of the transverse ligament. On examining more carefully, however, I soon found that the upper bundle of transverse fibres, which caused the apparent increase in depth of that ligament, was attached—not to the lateral masses of the atlas, but—to either margin of the *foramen magnum*, and formed a strong, rounded, and perfectly separate ligamentous cord, stretching across the *foramen magnum* from the posterior part of the tubercle for the check ligament on one side to the corresponding point on the other. Its lower margin, which had at first sight appeared to be fused with the transverse ligament, was found to be easily separated from the latter, as the adjacent margins of the two structures were merely connected by a little loose areolar tissue. The *appendix superior* ascended from the upper margin of the transverse ligament, behind the other band, to its usual point of attachment.

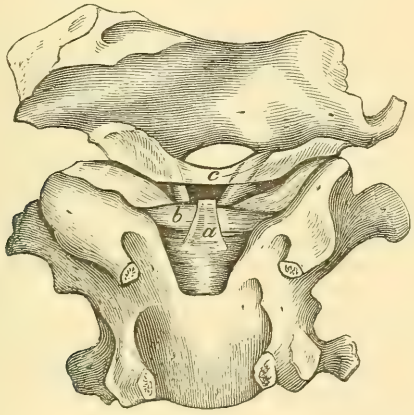

Fig. 2 gives a good idea of its relation to the check ligaments: the latter were exposed by division of the other ligaments connecting the atlas with the occipital bone, and then separating the two bones by traction—*a*, superior appendix of cruciform; *b*, upper part of transverse ligament; *c*, ligamentum transversale occipitale.

When the latter structure was forcibly drawn upwards from the upper margin of the transverse ligament, the apex of the odontoid process was brought into view, and the check ligaments were seen proceeding therefrom, one on either side, obliquely outwards and upwards, with a slight inclination forwards to their usual points of attachment, which in this case was immediately in front of, and indeed partially blended with, those of the ligament which forms the subject of the present communication.

Having never before met with anything similar to this ligamentous band, my curiosity was considerably excited by its appearance, and this feeling was not diminished when I found, on showing

the specimen to Professor Macalister, that no corresponding structure had been observed by him before. He informed me afterwards, however, that a ligamentous band, having the position and attachments of the one in question, was described by Lauth as a normal structure in human anatomy. Lauth has given it the name of *ligamentum transversale occipitis*, and describes it in the following words:—"Unmittelbar über diesen Bändern[1] findet man das Queerband des Hinterhauptbeins (L. transversale occipitis), welches von einer seite des Hinterhauptloches an die andere geht, ohne sich an den Zahnfortsatzes zu heften."—(*Anatomie*, Bd. i. s. 101).

I have since found that it is noticed in the French work of Beaunis and Bouchard under the name of "*ligament transverse occipital de Lauth*" (8me ed. p. 133). These anatomists look upon it as being formed by the superior fibres of the check ligaments, passing, as they describe it, without interruption from one occipital condyle to the other, over the summit of the odontoid process. Luschka, in his very perfect description of the anatomy of this part, also observes that it is not unusual for the uppermost bundles of fibres of the check (superior lateral) ligaments to interlace with one another so as to form an *upper ligamentum transversale*. From his description, however, I am not disposed to think that he ever saw it largely developed as an independent structure. Henle (Bänderlehre) also describes an inconstant *membranous* band formed by a few of the fibres of the check ligaments interlacing with one another in the middle line behind the upper part of the odontoid process, and so stretching across from one occipital condyle to the other; but even he does not mention any case in which it had been seen to attain anything like a considerable size, although he quotes all the known deviations from normal structure in this as well as in other regions of the human body. A slight allusion is also made to the interlacement of some of the upper fibres of these ligaments in *Quain's Anatomy* (8th ed.), but not in such a manner as to lead the reader to expect that a strong separate band might be found in this situation.

From the evidence brought forward, I think myself justified in describing the specimen before the Academy to-night as an anomalous structure, and one of some interest, as must all the structures be, normal and abnormal, which enter into the formation of the very important articulations which connect the vertebral column with the brain-case, and which, accordingly, are concerned in the preservation of the vital structures which lie in their immediate neighbourhood. I should, however, have hesitated to bring it under the notice of anatomists if I had not been encouraged by Professor Macalister; to whose kindness and courtesy I am indebted for the chief part of the information which I have been able to collect on the subject.

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[1] *i.e.*, Ligamenta alaria.

LIV.—Note on the Occurrence of a Premaxillo-frontal Suture in the Skull of the Koala (Phascolarctos cinereus). By H. W. Mackintosh, Professor of Zoology, Trinity College, Dublin. (With Plates X. to XIII.)

[Read, November 29, 1879.]

In the collection of the Museum of Anatomy and Zoology of the University there is a skeleton of the marsupial Koala (*Phascolarctos cinereus*, Fischer), the skull of which, while normal in other respects, exhibits a distinct contact between premaxillæ and frontals, an arrangement which, so far as I can ascertain, has not yet been described. The animal to which the skeleton belonged had been obtained some years ago by Professor Macalister (to whose courtesy I owe the present opportunity of describing the skull), who published an account of its anatomy in the *Annals and Magazine of Natural History for* 1872, Vol. x. p. 127.

In the Museum of the Royal Dublin Society there is another skeleton of Koala, the skull of which Dr. Carte, the Director of the Museum, has kindly allowed me to examine; and in it I find also a premaxillo-frontal suture, but it is apparent only on the right side, where it is very small, being less extensive than that on the left side in the specimen here figured. In their general features they both agree with the descriptions given in manuals and memoirs, and on comparing them with the drawing published by Owen,[1] I find that the resemblance is sufficiently close in other respects.

In its cranial osteology the genus Phascolarctos departs, as is well known, from many of the characters of the Didelphs, and suggests sundry resemblances to Monodelphian skulls. Thus, for instance, the zygomatic arches are very long, and run parallel to the axis of the cranium, as in no other living marsupial, and only to a comparatively slight degree in the fossil Nototherium. Then we notice the large tympanic bullæ (which have been compared to those in the pig), the abruptly truncated nasal aperture, the rounded premaxillæ, the prominent paroccipital processes, and the vertical supra-occipital, all rodent characters, and each of which connects the Koala with some other marsupial genus, as I shall presently point out.

On examining the anterior part of the skull (Plate X., fig. 1), it will be seen that the ascending process of the maxilla (7), which, in all the other marsupials which I have examined, comes into contact with the nasal (8) of its own side, and interposes between the premaxilla (9) and frontal (4), is here shorter than usual, and thus these two bones come into contact slightly, but distinctly, on the right side, and to a much more marked degree on the left. In a skull of the same animal,

[1] "On the Fossil Mammals of Australia," *Phil. Trans.*, vol. clxii. part 1.

in the Museum of the Royal Dublin Society, the arrangement differs slightly from this, for there the suture on the right side is present, though much smaller than that figured above, whilst on the left side a very small bar of bone, not more than one-twentieth of an inch in width, runs across from the frontal to the maxilla, and prevents the contact of premaxilla and frontal.

As there are only the two skeletons of the Koala in Dublin, I cannot say whether this suture is characteristic of the genus; but in the drawing of the skull published by Owen[2] there is no appearance of it, nor in the various allusions to it which I have met with can I find any notice of it. On the contrary, it is generally laid down as a character of the marsupials, that the premaxilla never quite reaches the frontal, so that I am inclined to think that its presence in these two specimens is due rather to individual variation.

As regards the degree of extension of the premaxilla on the upper surface of the skull, there is a good deal of difference amongst Didelphs, as may be seen by the figures which I have drawn from specimens in the Museum of Anatomy and Zoology. Thus *Phascolomys fossor* (Plate XIII., fig. 8) has the largest premaxilla,[3] which exceeds that in *P. latifrons*, Owen (Plate XI., fig. 4). Next in order would seem to come *Phalangista vulpina*, Desm. (Plate XIII., fig. 9), where the premaxilla is of a massive character, like that of Phascolomys; then would come *Halmaturus ualabatus*, Less. (Plate XII., fig. 6), and its ally *Macropus gigantea*, Shaw (Plate XII., fig. 5), which scarcely, if at all, proportionally, exceeds *Sarcophilus ursinus*, Geoff. (Plate XIII., fig. 10); and finally, there is *Didelphys cancrivora*, Gomel (Plate XII., fig. 7), in which there is about the smallest extent of premaxilla, at least in the series which I have examined. There is, however, in the Museum a skeleton of *Petaurus ariel*, Gould, in which the premaxilla seems to reach very nearly, if not quite, up to the frontal; but the ossification of the skull has been so complete that the sutures are almost entirely obliterated, and I have not been able, in spite of careful examination, entirely to satisfy myself of their contact.

In comparing the skull of the Koala with those of other marsupial genera, we may notice that, while possessing strongly marked characters of its own, it presents many features which are repeated in the other forms. Thus we notice the parallel zygomata, as in Nototherium; the large tympanic bullæ, like those of Petaurus; the large par-occipital processes, which resemble those in the Kangaroo, to which there is a further likeness in the rounded premaxillæ; the vertically placed supra-occipital, as in Phascolomys, and the truncated nasals resembling those in Sarcophilus.

A premaxillo-frontal suture does not appear to be common amongst mammals, nor, indeed, amongst vertebrates. It is to be

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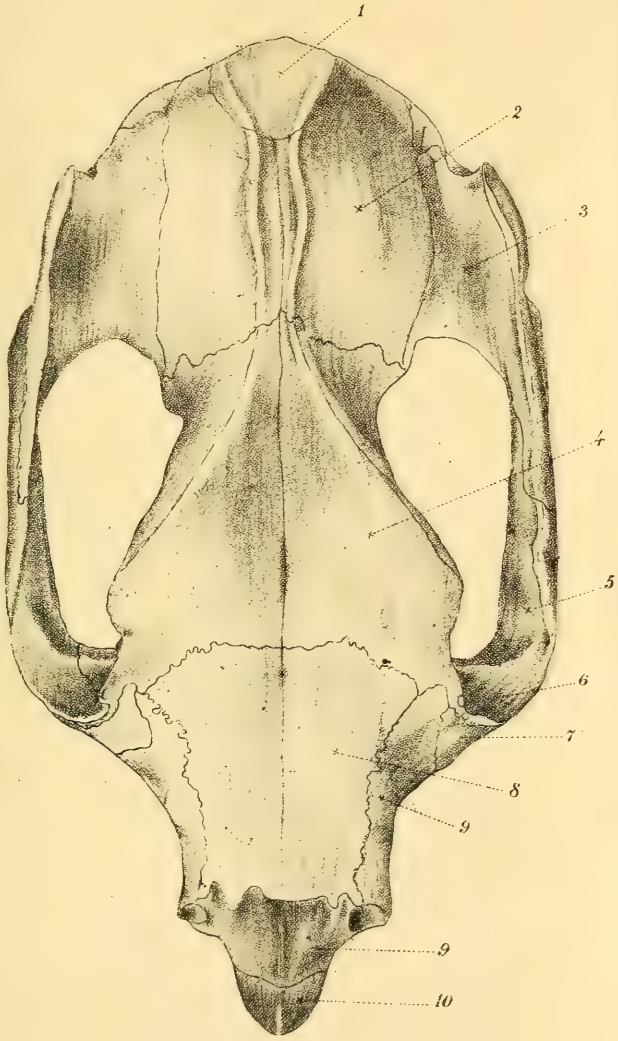
[2] "On the Fossil Mammals of Australia," *Phil. Trans.*, vol. clxii. part 1.

[3] Owen says that Phascolomys has the largest premaxilla, but he seems not to have met with a Koala with a premaxillo-frontal suture.



H.W.M. ad nat.

Forster & Co., Lith. Dublin.

Fig. 2.

H.W.M. ad nat.

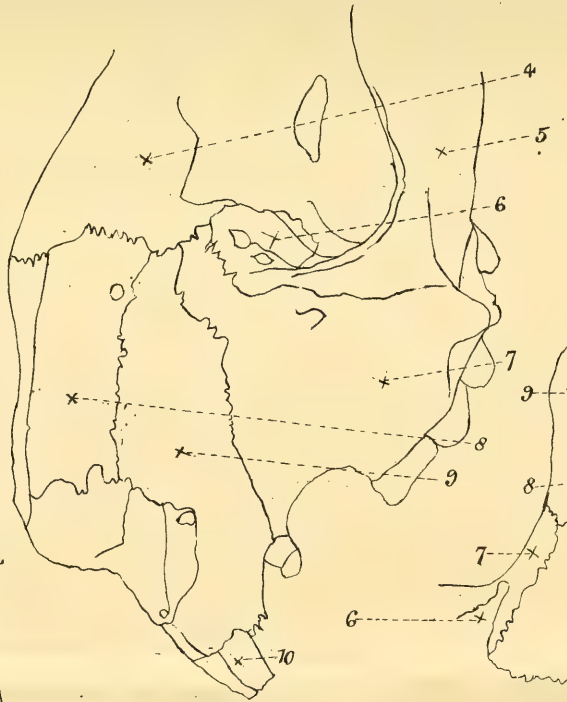


Fig. 3.

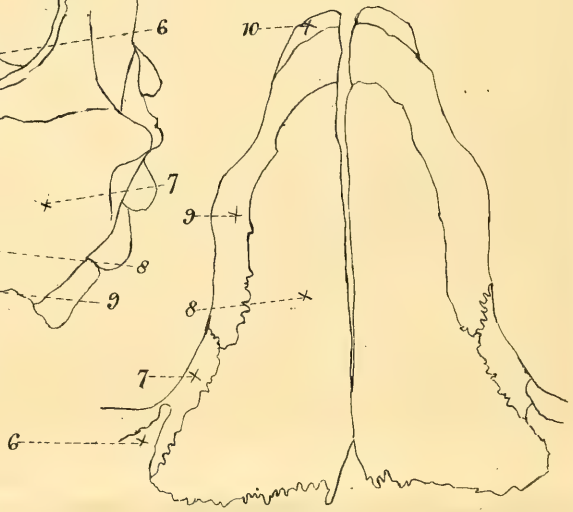


Fig. 4.

Forster & Co., Lith: Dublin.

Fig. 5.

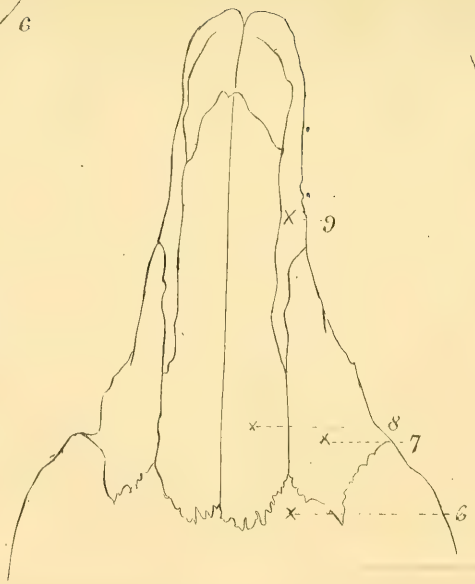


Fig. 6.

Fig. 7.

H.W.M. ad nat.

Forster & Co., Lith. Dublin.

found, so far as I know, generally in Cetaceans, in the elephant, and, as a rule, in Rodents, the hares being a frequent exception. I have observed a very small, but distinct, suture on both sides of the skull in the hedgehog, but it does not exist in the specimens of Centetes and Myogale, which are the only other genera of Insectivora, the skulls of which are in the Museum. In all the other classes of mammalia the premaxillæ are either small, or even when of considerable extent are prevented from reaching the frontals by the greater development of either nasals or maxillæ.

DESCRIPTION OF THE PLATES.

The following references are adopted throughout:—

1. Supra-occipital.
2. Parietal.
3. Squamosal.
4. Frontal.
5. Jugal.
6. Lachrymal.
7. Maxilla.
8. Nasal.
9. Premaxilla.
10. Tooth.

PLATE X.

Fig. 1.—Skull of Koala seen from above, showing the premaxillo-frontal suture well marked on the left side, and its extension on the right.

PLATE XI.

Fig. 2.—Anterior part of same skull, right side.
Fig. 3.—Anterior part, left side.
These figures are slightly enlarged, and are introduced to show the relations of the premaxillæ and frontals, without the fore-shortening, incident to a top view.
Fig. 4.—Anterior part of skull of *Phascolomys latifrons* seen from above.

PLATE XII.

Fig. 5.—Anterior part of skull of *Macropus gigantea* seen from above.
Fig. 6.—Anterior part of skull of *Halmaturus ualabatus* seen from above.
Fig. 7.—Anterior part of skull of *Didelphys cancrivora* seen from above.

PLATE XIII.

Fig. 8.—Anterior part of skull of *Phascolomys fossor* seen from above.
Fig. 9.—Anterior part of skull of *Phalangista vulpina* seen from above.
Fig. 10.—Anterior part of skull of *Sarcophilus ursinus* seen from above.

The figures from Plate XI., fig. 4, to Plate XIII., fig. 10, are intended to show the extension upwards of the premaxilla towards the frontal in the different genera and species which I have been able to examine. All the figures are natural size, except figs. 2 and 3, which are slightly enlarged.

LV.—Eurites, or Basic Felstones of Silurian Age. By G. H. Kinahan and Gerrard A. Kinahan.

[Read, April 26, 1880.]

In the Irish Silurians, that is, including under this name both the rocks containing the typical Silurian fossils, and also those commonly called Lower Old Red Sandstone (the "Glengariff grits," and "Dingle beds" of Jukes), there are felstones which seem to be typical of the formation. They are basic, the "Eurites" of Daubuisson (from *eureo*, to flow easily, on account of the facility with which they melt before the blow-pipe), and belong to the "Hybrid rocks" of Durocher. The geological position of the Silurian eurites is fully given in the Report on the Rocks of the Ballaghaderreen and Fintona districts.

In Munster, the granitic roots of these rocks have not been observed, although in places in the intrusive portions they partake more or less of elvan characters, as they contain free quartz; in Galway, however, they can be traced down into a true granite, and in N. E. Mayo into elvan; while in Tyrone there are granites and elvans which are evidently the granitic roots of the interbedded eurites. What may be an important character in these rocks is the presence of carbonates of iron and lime; sometimes abundantly. In this Report, it is proposed to describe some of the euritic rocks of Kerry, N. W. Galway, and S. W. Mayo.

We are indebted for valuable aid to Professor O'Reilly, M.R.I.A., of the Royal College of Science, who allowed us the use of his well-arranged mineralogical laboratory and his microscopes, besides free access to his excellent type collections of rocks, minerals, and microscopic slides.

During our examination we have consulted several works on the microscopical study of rocks, especially those of F. Rutley, on *The Study of Rocks;* F. Zirkel, *Microscopic Petrography;* and F. Fouqué, *Santorin et ses eruptions.*

Part I.—*Rocks of Kerry, N.W. Galway, and S.W. Mayo.*

In the counties Kerry and Cork, south of a line drawn east and west along Dingle Bay, the Silurian rocks are of the type called by Jukes "Glengariff grits." In these rocks there are masses of eruptive rocks appearing in the vicinity of Valentia harbour, and southward of Killarney, in the neighbourhood of Lough Guitane, between Mangerton and Glenflesk.

In the vicinity of Valentia harbour the majority of the eruptive rocks are so basic that they must be classed as either gabbros or dolerites; but those near Lough Guitane are eurites of Daubuisson, and belong to the typical basic felstones of the Irish Silurians.

From the latter area two specimens are exhibited; both show the gradual merging of the rock into elvan, as they contain free quartz. This, however, might be expected, as one of the specimens is from the intrusive mass, while the other is from the vicinity of it.

That from Lough Guitane, near Killarney, is a specimen of a dark-green feldspathic rock; it has a specific gravity of 2·63. The macroscopic examination of it shows it to consist of a finely granular ground-mass or matrix, scattered through which are small crystals of feldspar, some of which appear to be orthoclase, while others are triclinic; some have striæ on the basal section, some are of an opaque white, with bluish tinge; there are also crystals and blebs of quartz. On looking through a thin section of this rock, a structure appears in the ground-mass which might be described as a banding, being a series of alternate semi-opaque and more pellucid parallel bands. The feldspar is cloudy, the quartz clear.

Microscopically, the ground-mass of this rock consists of a crypto-crystalline base, with numerous crystallites of feldspar (both orthoclase and triclinic) quartz, small fragments apparently of hornblende; in some places long acicular crystallites or crystalloids, sometimes grouped radially, which are clear and pellucid. A chloritic mineral (viridite), and a dusty-looking opaque granular mineral (opacite) occur plentifully, ferrite sparingly. In a few places aggregate polarization occurs, consisting of a clear, circular portion with a dark cross, which rotates on rotating the polarizer, but remains stationary on rotating the slide. The banding noticed in the macroscopical examination seems, with polarized light and under a power of one hundred diameters, to be due to a difference in the degree of crystallization, the more largely crystalline bands being the more pellucid. In this ground-mass are developed the macroscopical crystals of feldspar and quartz. The feldspars, as already mentioned, are both orthoclase and triclinic; some of them being very peculiar, showing a remarkable banding or interlamination under polarized light. Under ordinary light they appear rather clouded, from containing opacite; some of them are imperfect, and seem to have been broken subsequently to their formation, some of the ground-mass having evidently intruded between the fractured portions. The bright little specks occurring in these feldspars under polarized light are found, when examined under a higher power (300 diameters), to be little iridescent patches, and are probably thin films of calcite. On applying hydrochloric acid to the specimen, a slight effervescence takes place, about and along certain lines in the feldspars, and at little specks through the ground-mass, indicating, probably, films and specks of calcite. Large quartz crystals are not well represented in the slide; generally the quartz is in small, rounded patches, though in some cases in well-crystallized forms; all are clear. Some of the larger pieces contain stone enclosures.

The specimen from Binaunmore, Co. Kerry, is that of a compact, olive-green rock, having a specific gravity of 2·63. The ground-

mass or matrix shows a minutely granular texture; in it are enclosed small rounded blebs of quartz, with crystals (some twins of the Carlsbad type) of orthoclase and of triclinic feldspars; some of the latter are like labradorite. In thin sections the feldspars are generally of an opaque white, and are apparently much altered. There are also small fragments of a greenish mineral, having their longer axes lying in one general direction, giving the slide a foliated appearance. In the specimen a few crystals of a green earthy mineral are visible, probably an altered hornblende.

Microscopically, the ground-mass of this rock is cryptocrystalline; that is, though evidently crystalline, the component minerals are not recognisable. Scattered plentifully through it is a fine opaque dusty-looking mineral (opacite), and a green chloritic mineral (viridite), which, together, give the slice a banded or fluidal structure, circling round and tailing out behind the larger crystals. Scattered through the ground-mass are the macroscopic crystals of feldspar, which, in general, have not sharply-defined angles. In many cases, under ordinary light, they have very much the same structure as the surrounding matrix, being scarcely distinguishable from it, except on account of a clearer margin along the boundary, while in other cases they are more impellucid than the matrix; but under polarized light they are plainly discernible; as under crossed Nicols the matrix presents a speckled grey appearance, while the feldspars are either of a uniform light tint, or else exhibit the banded structure, with iridescent specks, as detailed in the description of the Lough Guitane rock. The quartz is clear, but contains bays and enclosures of the matrix (stone enclosures).

At Clogher Head, Dingle Promontory, the eurites appear to be interstratified with rocks containing typical Silurian fossils. The specimen taken thence is a pink-brown-coloured eurite, having a specific gravity of 2·71. The ground-mass is a pink-brown feldspartic matrix, through which are scattered small crystals of orthoclase (some Carlsbad twins), and triclinic feldspar (probably both labradorite and oligoclase). These crystals are mostly long and slender; but some are broken, apparently along a twin plane, and the ground-mass is forced in between the fractured portions. In thin sections there is a banded appearance in the slice, some of these bands being more impellucid than the rest; they lie in one general direction. On treating the specimen with hydrochloric acid, effervescence takes place around some of the triclinic feldspars, also along lines or cracks, and at little specks through the ground-mass.

Microscopically, the ground-mass is composed of a microfelsitic base, containing small crystalline particles of quartz, feldspar, viridite, and opacite, exhibiting a slight fluidal structure. Through this microfelsitic base are bands having a microcrystalline structure, composed of quartz and feldspar; and through this ground-mass are developed porphyritically crystals of orthoclase feldspars, more or less clouded, with twinning, some being broken. There are also feldspars

exhibiting the interlamellar structure described in the previous rocks. Most of the crystals contain numerous enclosures, some of which are recognizable as chlorite and opacite. Alteration appears to have taken place extensively through the mass; secondary products, some of which appear to be calcite, occur, filling up the interstices.

At Loughnafooey and the adjoining country, both in Galway and in Mayo, are large tracts of eurites and their associated tuffs, partly intrusive, but generally interbedded. The specimen examined is from one of the intrusive portions, and has a specific gravity of 2·62. The ground-mass or matrix of this rock is very slightly granular, and through it are scattered fragments of quartz, as also rounded portions of a waxy-looking feldspar, probably triclinic; in some of these an effervescence takes place, when the specimen is treated with hydrochloric acid, probably due to films of calcite in cracks through the minerals. Small earthy portions, having the form of orthoclase, occur through the mass, as also fragments of a dark-green mineral.

Microscopically, the ground-mass is cryptocrystalline, and through it occur fragments and crystals of quartz, feldspar, and microlithic portions of hornblende. Ferrite is sparingly represented; opacite occurs plentifully, particularly round the edges of the quartz. The feldspars are, for the most part, more or less decomposed, but triclinic twin structure is still apparent in many; in others there is left but an outer shell, the whole interior being replaced by an earthy, almost impellucid, substance. In places there are fragments of calcite; in one case, a fragment of what was apparently once feldspar is now represented by calcite. Apatite is recognizable in long acicular crystals in some of the more pellucid feldspars. Some of the feldspars show the interlamellar structure before described. The fragments of quartz are clear, and contain some large stone enclosures and glass cavities.

In the Silurians north of Killary Harbour, at Bundorragha, and to the west and east thereof, there are thick interbedded masses of eurites, from one of which the specimen now to be described was taken, the rock having a specific gravity of 2·66. There are some remarkable differences between this rock and that next to be mentioned; as, although both are from the same neighbourhood, there is in the latter a considerable quantity of carbonate of iron, although at the same time its specific gravity (2·60) seems to be lower. The ground-mass is a dense purple-brown matrix, having a slightly resinous lustre, through which are scattered crystalline particles, which, though tolerably abundant, are relatively small, and consist of quartz and feldspar, the latter mostly having a pearly lustre; some present a structure that is very like that of labradorite. In thin sections the ground-mass appears brown and fine-grained; and scattered through it are some comparatively large crystals and patches of quartz, containing stone enclosures, as also numerous small patches of clouded feldspar.

Microscopically, the ground-mass might be described as a micro-

felsitic base, with numerous minute microcrystalline particles scattered through it. Through this matrix are scattered crystals and fragments of feldspar, both orthoclase and triclinic; the latter being the more abundant, though the fragments are, as a rule, smaller than those of orthoclase. Many of the fragments are clouded, some greatly altered, so that it is difficult to say whether they are orthoclase or triclinic; in a few cases, both varieties appear to occur in the same particle. The interlamellar structure before described is to be observed in some. The quartz crystals contain stone enclosures, while chlorite and opacite occur in the ground-mass; the former were also observed in some of the quartz crystals. Through the ground-mass there are portions that seem to have been geodes; on the sides of these are microcrystalline particles of feldspar and quartz; the interstices have since been filled with some secondary product.

Another specimen, from the bedded masses near Bundorragha, has a specific gravity of 2·60. It consists of a brown felsitic ground-mass, having a finely-granular texture, through which are scattered blebs of quartz, and also crystals of feldspar having a pearly lustre, with patches of a brownish mineral (carbonate of iron) which effervesces copiously on the application of hydrochloric acid; effervescence also takes place in minute specks through the ground-mass, particularly at some little green patches, as if carbonate of iron were very prevalent in the rock. The slide shows the ground-mass to be composed of a compact brown matrix, through which are numerous minute fragments of a fibrous-looking mineral, a few large fragments of quartz, a clear feldspar with numerous irregular lines through it, also a clouded feldspar, and a brown mineral (iron). There are also minute cavities round which are incrustations.

Microscopically, the specimen consists of a cryptocrystalline matrix, alteration-products occurring plentifully; few recognizable minerals occur; but there is a cloudy altered feldspar, which appears to be orthoclasic, and also a clear, homogeneous, triclinic feldspar with numerous irregular lines passing through it, along which alteration has taken place; quartz is present in small quantities, and scales of iron carbonate.

LVI.—SUPPOSED UPPER CAMBRIAN ROCKS IN THE COUNTIES OF TYRONE AND MAYO. By G. H. KINAHAN, M.R.I.A., &c.

[Read, December 8, 1879.]

DURING the examination of the Fintona and Curlew Mountain districts, for the purpose of preparing the Report to the Academy thereon, the wild hilly tract of metamorphosed rocks extending from a little south of Cookstown westward towards Omagh was explored. In this area some of the more notable hills are Craigballyharky, Craigardhessiagh, Garragrim, Creggaunconroe, Carrickmore, &c. Reasons will now be given for believing that the metamorphic rocks of this district are of Cambrian age.

Let us first consider their stratigraphical position. This will be best determined, if it can be determined, by their apparent relations with the fossiliferous rocks of the small district at Pomeroy, which, from their fossils, are generally regarded, and with good reason, as Cambro-Silurian; though this cannot be said to be absolutely proved (they may well be of similar age to the English Caradoc). The principal points in favour of this conclusion are their similarity to the fossiliferous rocks which, at Lisbellaw, in the Co. Fermanagh, are undoubtedly covered unconformably by the red arenaceous Silurian rocks (Dingle grits). Moreover, in the low country a little north of Creggaunconroe, the numerous large angular blocks of the arenaceous red Silurian rocks seem to be nearly *in situ*, which would suggest that an outlier of these rocks rests directly on the metamorphic rocks. It has been suggested that these blocks have been carried northward to their present site by ice; but the weight of evidence seems to be against such a supposition. First, the shapes of the bosses of rock in the hills northward of Pomeroy seem to indicate that the ice was going southward; secondly, the drift of the country south of these hills is largely made up of the *debris* of these rocks; and thirdly, no large blocks of these arenaceous red Silurian rocks are found in the country between this assemblage of blocks and what are evidently their parent rocks near Pomeroy. This, however, although suggestive, is not of great weight; for if the ancient metamorphic rocks were hills in the Silurian sea, arenaceous deposits may have accumulated on one side, and argillaceous on the other. The age of these Pomeroy fossiliferous rocks is a subject that I hope to enter into more fully at a futnre time.

These altered eruptive and sedimentary rocks are undoubtedly of much greater age than the overlying fossiliferous Pomeroy rocks; as they were contorted, ruptured, upheaved, metamorphosed, and denuded prior to the latter accumulating on and against them. If the

Cambro-Silurian age of the Pomeroy fossiliferous rocks is conceded, it simplifies the matter; as the rocks in the hills to the north and north-west are much older, and must, therefore, belong either to the Cambrian or an older formation. To the northward and north-westward sides of the altered eruptive rocks of the hills there is a considerable thickness of apparently overlying schists, generally supposed to be metamorphosed Cambro-Silurian.

The conclusions I have drawn from the apparent stratigraphical position of the rocks now under consideration seem to be strongly confirmed by the petrological characters of the eruptive rocks associated with them.

In Craigballyharky and its neighbourhood the rocks are principally varieties of hornblende rock, that is, basic eruptive rocks and tuffs, which have been changed by metamorphic action. These, as is usually the case, are very variable in composition; as, however, they are more or less similar to the different varieties of hornblende rock in West Galway, elsewhere described,[1] it is unnecessary to re-describe them here. Traversing and breaking up through these rocks, especially in Craigballyharky, are veins of Galway granite of the "Omey type," and a black granite very like one found near Furbogh and in other places in West Galway, except that in the Co. Galway amphibole and titanite are not uncommon in it, while in the Co. Tyrone they seem to be rare.

In the neighbouring hills (Craigardhessiagh and Garragrim) the rocks, for the most part, belong to an intrusion of the "Omey type" granite. They are, however, more or less cut up and traversed by dykes and courses of a very siliceous compact granite, common as a vein rock in Galway, and similar to the rock called granitite by Rose. The mass of the granite in this hill has been called "Syenitic granite," by which, I suppose, hornblendic granite is intended. The rock, however, seems scarcely to come under this classification, as its essential constituents are quartz, two, and in places three, feldspars, black and white micas, the first predominating; pyrite, and in places amphibole: the last, however, seems to be more an accessory mineral than an essential. In every respect this rock agrees with that described in the *Memoirs of the Geological Survey* as the "Omey type" of the Galway granite.

In the western part of the district now described, the rocks are principally varieties of hornblende rock very similar to those found in Errisbeg, Errismore, and other places in West Galway; while here, as there, some of the rocks are changed by methylotic action into ophite, steatite, and allied rocks. These rocks in West Galway are found in the uppermost portion of the "Great Micalite series," which,

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[1] "Granitic and other Ingenite Rocks of Yar Connaught and the Lower Owle," *Proceedings R. I. A.*, 2nd ser., vol. ii., p. 102, *et seq.*

I think, are probably equivalents of part of the "Arenig group" of Wales, put by some geologists among the Cambrians.

These two lines of evidence, stratigraphical and petrological, point to the same conclusion, that these Tyrone rocks now in question are of Cambrian age.

It may here be mentioned incidentally, that breaking up through these metamorphic eruptive and sedimentary rocks are masses of a much more recent granite, or elvan, similar to the pre-Carboniferous granite rocks at Carndaisy, Co. Derry, and more or less like the granite and elvan of Lugnanoon, Co. Galway. As this granite, in the intrusion near Mullanmore Bridge (north of Carrickmore, or Termon Rock), graduates into elvan, and the latter into a quartzitic eurite, closely allied in composition to the eurites which, south of Pomeroy and elsewhere, are interstratified with the arenaceous red Silurian rocks, we have a right to suppose that here, as in West Galway, and South-west Mayo, these granites and elvans are the granitic roots of the Silurian bedded eruptive rocks.

The second tract to which I would direct attention is in North-east Mayo, southward of Charlestown, and westward of Ballaghaderreen. The rocks of that area were classed by Griffith, and subsequently by Jukes, as ancient metamorphic rocks; but more recently they have been called "Felstones" and "Upper Silurian."

Mapping some of these rocks as felstones is so far correct, that the rocks so called are granulites, or leptynites (metamorphic felstone), rocks which many petrologists include among the felstones;[2] but mapping any of them as "Upper Silurian" must be incorrect, as it is evident that these metamorphic rocks were ruptured, upturned, metamorphosed, and denuded prior to the still unaltered Silurian rocks being deposited on them. In the conglomeritic Silurian rocks of Cranmore and elsewhere fragments of these metamorphic rocks are conspicuous.

These metamorphic rocks in the country southward of Charlestown are in many respects very like those in the Tyrone hills to the north of Pomeroy; but we cannot speak of them so confidently, because—

First, only a small tract is exposed, which at one side is overlaid unconformably by Silurian rocks, and on the other by Carboniferous; therefore, although we are aware that they must be older than the Silurian, yet we cannot positively prove that they do not belong to the Cambro-Silurian.

Secondly, in many respects they are more or less similar to some of the rocks of the *Doolough and Lettermullen series* (S. W. Mayo and West Galway), in which are fossils pronounced to be Cambro-Silurian.

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[2] Rutley says that granulite, or leptynite, has the same relation to felstone as gneiss has to granite.

What I, therefore, now put forward in respect to the Cambrian age of the rocks now in question is only conjectural. It would appear to me that they are a portion of the rocks which occur in the hills called Benbo and Slieveslish, south and eastward of Lough Gill, Co. Sligo. These latter rocks are very similar to some of the lower rocks in the West Galway section ; rocks which, as shown in former Papers read before the Academy and elsewhere, are probably Upper Cambrians below the passage beds between the Cambrian and Cambro-Silurian formations.

LVII. — ON THE OSTEOLOGY OF TWO NEGROES. By ALEXANDER MACALISTER, M. D., Professor of Anatomy and Chirurgery, University of Dublin.

[Read, November 30, 1880.]

Two well-grown male adult Negroes were received, in the ordinary course of subject-supply, in the Dissecting Rooms of the University, and, as in this country the opportunities of such dissections are rare, I put their bodies into the hands of the most careful and senior of our students, who, under my constant personal superintendence, made very thorough examinations of all the systems of their bodies.

In this and the following short records I have summarized the results of the notes made by these gentlemen.

It is rather remarkable that while in the ordinary course of things it might be expected that Negroes would form a large proportion of the subjects dissected in America, yet the anatomists of that country have not given to us, in anything like an exhaustive manner, a record of the presence or absence of peculiarities. The few meagre anatomical notes hitherto published in that country are only sufficient to stimulate the curiosity of anatomists, not to satisfy it.

The Negroes were both of pure African descent, well developed, full-grown, born in the West Indies, sailors. No. 1 was smaller, older, about 44; No. 2 was 5 feet 11 inches in height, largely developed, younger, about 35. The skeletons of both have been carefully prepared, and are now placed in the Ethnological Collection in the College Museum. From these I have made the following notes:—

The skull of No. 1 is prognathous, dolichocephalic, mesoseme, platyrhine, hypselocephalic, mesorhine. Its facial angle, as measured by the alveolar index, is 1066, and its measurements are as follows:—

Fronto-iniac arch 310 mm., long diameter 178 mm.; intermastoid arch 370 mm., intermastoid diameter 128 mm., greatest width 131 mm.; height 139 mm.

The sagittal suture is partly ankylosed, simply toothed. There is a large left and small right parietal foramen; a small wormian bone in the parieto-mastoid suture on each side; a short sphenoparietal suture 13 mm. long on both sides. There is no posterior condyloid hole, and the condyles are unsymmetrical, the right being shorter and divided into two facets; the left longer and undivided. The right anterior condyloid hole is divided by a septum, and the jugular eminences are large, projecting on one side into a kind of paramastoid process, while there is a small spur in front of the left condyle like a trace of the third occipital condyle.

The temporals have large mastoid processes, a post-glenoid fissure, a bony bridge crossing the jugular foramen on each side internally,

and a smaller bony bridge passes from the carotico-jugular crest to the ex-occipital. The right foramen spinosum is in the line of the suture, and the scaphoid fossa is continuous down to the hamular process.

The nasal bones are prominent, ridged, narrow above and wide below; the lachrymal has a sharp crest, a middle and inferior process, a short lachrymo-ethmoidal suture 1 cm. long. The malar has a posterior temporal process, and the infra-orbital canal is very oblique, looking downwards and inwards, with a sharp crescentic outer edge. The anterior nasal spine is double and prominent.

The teeth are large, the lower molars with much-wrinkled crowns; the third lower has its fifth hindmost cusp large, and its other cusps divided by secondary furrows. The right third upper molar is nearly as large as the first, and a diastema, 6 mm. long, intervenes between the second premolar and the first molar on the right side above.

The lower incisors are strongly curved, concave backwards. The alveolar parabola of the lower jaw measures 57 mm. from before backwards, and 62 mm. transversely across the third molar. The semi-ellipse of the upper teeth is 50 mm. in its semiaxis major and 62 mm. in its axis minor. .

The mandibles are large, strong, 87 mm. from angle to angle, 70 mm. in height at the condyle, which was 29 mm. in transverse breadth; the outer points of the two condyles were 125 mm. apart, while the inner were 77·5.

The skull of No. 2 was larger, finer, more massive, prognathous, dolichocephalic, cryptozygous, microseme, platyrhinal, and having the the following measurements:—Greatest length 188·5 mm.; greatest breadth, supramastoid 136 mm., interparietal 132 mm.; greatest height 140 mm.; fronto-iniac arch 350 mm.; intermastoid arch 380 mm.; orbital index 75·5; cephalic index 72·3.

In many respects it resembled that of No. 1, but showed the following differences:—

The coronal suture is uncommonly gyrated on each side, and the spheno-parietal suture is absent, as the squamosal on both sides articulates with the frontal. The left occipital condyle is wider and longer, the right narrower and shorter, and both anterior condyloid holes are undivided, both posteriors wanting. The stylohyals are short, while in No. 1 they are very long, ankylosed, and the jugular holes are only imperfectly bridged. The upper band of the pterygo-spinous ligament is ossified, and the scaphoid fossa is small. The nasal bones are typically flattened and nearly of equal width throughout; the lachrymal has a very short ethmoidal suture, 8 mm. long, and a slight trace of a superior process.

The scapular index of No. 1 is ·73°, of No. 2 is ·71. In No. 1 the clavicles are markedly unsymmetrical, the right being 150 mm., the left 132 mm. long. The left humerus has an intercondyloid perforation. The tibiæ are nearly platycnemic; and each femur has a well-marked tuberculum colli anterior.

The sacrum is short and curved, somewhat like that of a small female, and the first rib articulated with the seventh cervical on the left. The atlas has a complete (left) and an incomplete (right) bridge on the posterior arch over the vertebral artery.

No. 2 is a much more massive skeleton, with two small ribs on the first lumbar vertebræ, a perfectly detached first sacral vertebræ; the sacrum with a strong downly-directed spur on its lower left side. The ossa innominata were enormously solid; when dried, one weighed 1lb., the other $\frac{3}{4}$lb. All the bones have their crests much exaggerated.

The femur has a strong supra-condyloid spur; the calcaneum projects an inch and three-quarters behind the tibia.

The humeri are very much flattened at their lower end, and the forearm bones are markedly unsymmetrical on the two sides.

The special points of interest in these two skeletons are: 1st, their respective intermembral lengths; 2nd, their general cranial characters.

APPENDIX A.

TABLE OF MEASUREMENTS.

	No. 1.	No. 2.
Right Radius, greatest length,	26·3	28·1
Left Radius, ,, ,,	25·5	27·2
Right Ulna, ,, ,,	29·0	29·7
Left Ulna, ,, ,,	27·9	29·4
Right Humerus, ,, ,,	31·3	33·5
Left Humerus, ,, ,,	30·7	33·5
Right Clavicle, ,, ,,	15·0	15·5
Left Clavicle, ,, ,,	13·2	15·5
Femur, ,, ,,	46·0	47·0
Tibia, ,, ,,	38·0	42·0
Fibula, ,, ,,	38·0	40·0

APPENDIX B.

Table of Indices.

	No. 1.	No. 2.
Intermembral (right), ...	71·0	71·0
Intermembral (left), ...	69·0	70·0
Femoro-tibial, ...	82·6	89·3
Tibio Fibular, ...	100·0	95·2
Humero-radial (right), . . .	84·0	85·1
Humero-radial (left), ...	83·0	82·4
Humero-ulnar (right), . . .	95·0	89·0
Humero-ulnar (left), ...	90·0	90·0
Radio-ulnar (right), ...	90·0	91·0
Radio-ulnar (left), ...	94·0	92·0
Altitudinal Cephalic, ...	78·0	74·0
Latitudinal Cephalic, ...	73·5	72·3
Orbital, ...	86·8	81·7
Nasal, ...	50·0	57·0
Scapular, ...	73·0	71·0

LVIII.—Three Years' Observations of the Tides at Liverpool (Fleetwood). By the Rev. James Pearson, M.A., F.R.A.S., late Scholar (15th Wrangler) of Trinity College, Cambridge, Vicar of Fleetwood.

[Read, December 13, 1880.]

It is now two years ago since I last had the honour of addressing the Academy on the above subject, and it is ten years at least since I first began a close application to the study of it. During all this interval I have been making a continuous system of observations, and have compared them with the results of theory, so as to form an exact opinion as to whether the method of computation which my own investigation led me to adopt was true to nature. It is a subject which becomes more fascinating the more it is indulged in. Few care to give to it the attention it deserves, and fewer still have the opportunity of noting the effect of barometric changes and atmospheric gradients so as to eliminate these disturbing causes from the general effects. Mrs. Somerville designated the state of the theory of the tides in her time as "a reproach to science"; and even Dr. Whewell, in his "History of the Inductive Sciences," complains of want of success. Under those circumstances there is every encouragement to persevere in the study. Like an unploughed field, it demands cultivation, and the more because so few care to work in it. Although recently a renewed effort has been made, and a fresh theory, based on a Harmonic Analysis, has been adopted, aided by a complicated and expensive machine which is to facilitate calculation, yet no practical tables have been forthcoming which may be submitted to the test of experiment, so far at least as one of the most important seaports of our country is concerned, viz., the Port of Liverpool. At this station we have two superimposed tides of 27½ feet mean range arriving at the same instant, or nearly so; and the force of gravitation may be as plainly seen in action as the movement of the machinery of a watch is discerned by noticing the motion of the seconds-hand. Hitherto the only tide-tables put into circulation have been (1) those published in the Isle of Man, (2) those originated by the Rev. George Holden, M.A., and printed in Liverpool, and (3) the Admiralty tables issued in London. The first are of more recent date than the second, but the mode of computation adopted in producing them is kept an inviolable secret. On this point Dr. Whewell writes as follows ("History of the Inductive Sciences," vol. ii., p. 255):—"Art, in this instance, having cast off her legitimate subordination to Science, or rather, being deprived of the guidance which it was the duty of Science to afford, resumed her ancient practices of exclusiveness and mystery. Liverpool, London, and other places, had their tide-tables, constructed by undivulged methods, which methods, in some instances at least,

were handed down from father to son, for several generations, as a family possession; and the publication of new tables, accompanied by a statement of the mode of calculation, was resented as an infringement of the rights of property." I am not aware that the mystery has even yet been divulged, though I am sure much progress has been made towards its solution by an independent inquiry.

The first object of such an inquiry is to ascertain the laws which regulate what is technically called the "diurnal inequality." This it is which causes the spring-tides sometimes to increase successively by irregular steps, each being alternately greater and less than the one preceding, and sometimes to succeed each other by continuous increments of height. This, though due to the changes of the moon's and sun's declination, as its ultimate cause, is much dependent on the configuration of land and water in the regions through which the tidal wave has to traverse; and Dr. Whewell's statement may still be safely endorsed—"Although Laplace's conjecture, that in the moving fluid the motions must have a periodicity corresponding to that of the forces, may in some cases of the problem be verified, this cannot be done in the actual case where the revolving motion of the ocean is prevented by the intrusion of tracts of land, running nearly from pole to pole." He adds: "I am not aware that for such a case anything has been done to bring the hydrodynamical theory of oceanic tides into agreement with observation."

Now it is precisely for the object of bringing theory into agreement with observation that the method has been devised to which I wish to call attention—a method which has been embodied for several years past in the Admiralty Tables. It is based on a modification of Sir John Lubbock's Tables, and rests on the equilibrium theory of Bernouilli, and it embodies the law which regulates the diurnal inequality. I propose to submit the method to the same test to which all the other consequences of gravitation have been submitted, viz.—the calculation of tables, and the continued and orderly comparison of these with observation. In order to do this satisfactorily, we shall select a period of time when settled weather indicates that atmospheric disturbing causes have had a minimum effect, the error from accuracy being in each case pointed out, and a note being made of the atmospheric conditions.

Our first record will show ten successive tides in February, 1878:—

Date.	Calculation.	Observation.	Error.	Barom., Wind, &c.
1878.	ft. in.	ft. in.	in.	
Feb. 13, M.	19·7	19·7	0	29·9, S., slight.
E.	20·3	20·2	− 1	30·0, W., ,,
14, M.	21·2	21·0	− 2	,, S., ,,
E.	21·11	22·2	+ 3	,, ,, ,,
15, M.	23·8	23·9	+ 1	,, ,, ,,
E.	24·6	24·8	+ 2	30·1, S.W., fresh.
16, M.	25·10	25·8	− 2	30·2, ,, ,,
E.	26·6	26·4	− 2	,, S., slight.
17, M.	27·11	28·1	+ 2	30·1, S.W., fresh.
E.	28·0	28·8	+ 8	30·0, ,, strong.
18, M.	29·4	29·6	+ 2	,, ,, abating.
E.	—	—	—	

Our next comparisons shall be taken from the month of April in the same year :—

Date.	Calculation.	Observation.	Error.	Barom., Wind, &c.
1878.	ft. in.	ft. in.	in.	
Apr. 8, M.	23·3	23·6	+ 3	30·1, S.S.W., strong.
E.	22·10	22·10	0	,, S.S.E., ,,
9, M.	22·2	21·10	− 4	30·2, ,, ,,
E.	21·6	21·1	− 5	,, E., ,,
10, M.	20·8	20·11	− 3	,, ,, fresh.
E.	19·11	19·11	0	,, ,, slight.
11, M.	19·11	19·11	0	,, S.E., ,,
E.	19·8	19·6	− 2	,, ,, S., ,,
12, M.	20·2	19·11	− 3	,, S.S.E., ,,
E.	20·10	20·8	− 2	,, ,, calm.
13, M.	22·1	22·2	+ 1	30·1, S., ,,
E.	22·11	23·3	+ 4	30·0, S.W., signal out.
14, M.	24·5	24·5	0	,, ,, slight.
E.	24·11	25·3	+ 4	,, S., ,,
15, M.	26·6	26·7	+ 1	30·1, W.S.W., fresh.
E.	27·0	27·0	0	,, ,, calm.
M.	28·5	28·9	+ 4	,, S., slight.
E.	28·2	28·3	+ 1	29·9, S.W., ,,
M.	29·1	29·0	− 1	,, W., ,,
E.	28·9	28·7	− 2	,, W.S.W., ,,
M.	29·1	29·0	− 1	,, W., ,,
E.	—	—	—	

The months of August and September, 1880, shall supply our next quotations:—

Date.	Calculation.	Observation.	Error.	Barom., Wind, &c.
1880.	ft. in.	ft. in.	in.	
Aug. 24, M.	27·8	27·6	− 2	30·4, N.W., slight.
E.	25·6	25·6	0	,, N., ,,
25, M.	26·1	26·0	− 1	,, ,, ,,
E.	24·0	24·3	+ 3	30·3, S., Bar. falling.
26, M.	24·2	24·3	+ 1	30·2, ,, slight.
E.	22·6	22·10	+ 4	,, S.W., ,,
27, M.	22·7	22·4	− 3	30·3, calm.
E.	20·10	21·1	+ 3	30·4, N.W., fresh.
28, M.	20·5	20·4	− 1	30·5, ,, slight.
E.	19·2	19·7	+ 5	,, E., ,,
29, M.	18·8	18·9	+ 1	30·4, N.E., ,,
E.	18·7	18·4	− 3	30·3, ,, freshbreeze.
30, M.	18·8	18·8	0	30·2, E., slight.
E.	19·4	19·9	+ 5	,, S., ,,
31, M.	19·6	19·7	+ 1	30·3, calm.
E.	20·10	21·3	+ 5	30·4, S., slight.
Sept. 1, M.	21·1	21·6	+ 5	,, S.S.W., fresh; signal out.
E.	22·6	22·7	+ 1	30·5., S., slight.
2, M.	22·10	22·7	− 3	30·6., S.W., slight.
E.	24·3	24·2	− 1	,, ,, ,,
3, M.	24·4	24·0	− 4	30·5, N.W.W., slight.
E.	25·8	25·5	− 3	30·4, calm.
4, M.	25·6	25·6	0	30·3, S.S.W., calm.
E.	26·11	26·10	− 1	30·2, S.W., slight.
5, M.	26·5	26·6	+ 1	,, S.S.W., gusty.
E.	27·9	27·4	− 5	,, depression approaching.

In conclusion, it is only necessary to observe how important it is not only to ascertain the normal height of the tide, but also the amount of the correction to be applied in consequence of atmospheric disturbances. Where so many causes are combined, nothing but patient experience and judgment will effect this. The most likely means of obtaining an accurate prediction is to notice the successive changes of sea-level from day to day, and add or subtract accordingly.

LIX.—Researches on Annual Parallax, made at Dunsink. By Robert S. Ball, LL.D., F.R.S., Royal Astronomer of Ireland.

[Read, January 10, 1881.]

In the following Paper I give a brief sketch of some of the observations which have been made at Dunsink during the last two or three years. The full details will appear in the publications of the Observatory, Part V. Some of the results have already been recorded in the Journals which are more specially devoted to Astronomy (see *Monthly Notices*, R.A.S., Nov. 1880, Jan. 1881, and *Urania*, No. 1). The three objects to which I wish to draw attention are the stars known as 61 Cygni, P III 242, and Groombridge 1618.

(61 Cygni).

In 1838 Bessel commenced a series of measures from the central point between the two components of 61 Cygni to the two other stars

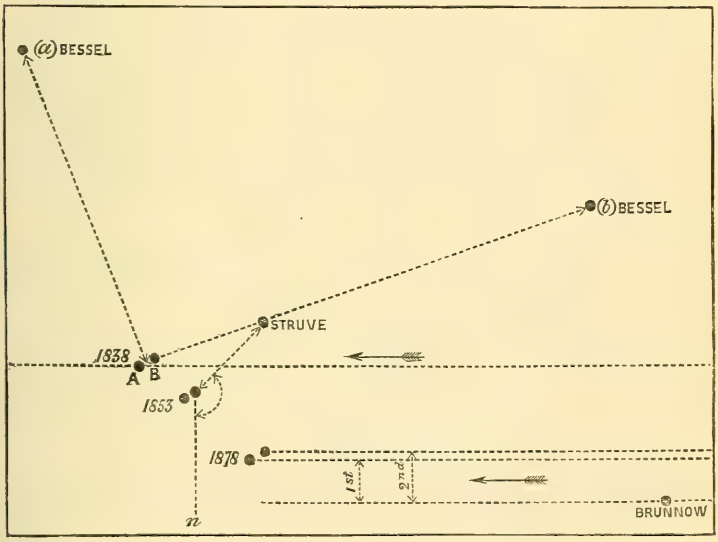

Fig. 1.—61 Cygni and Comparison Stars.

a and *b* (see Fig. 1). *a* is a star of the 8·8 mag., and is known as BD + 37°, 4173; while *b* is a star of the 8·6 mag., known as BD + 37°,

4179. The result of a most elaborate series of measures made with the heliometer gave for 61 Cygni a parallax of about one-third of a second.

Fifteen years later, Struve undertook a new determination of the parallax of 61 Cygni, which had by that time moved into the position marked 1853, Fig. 1. The comparison star employed by Struve was of the 9·4 mag., BD + 38°, 4345. He employed measures of the distance and position angle of 61 (B) Cyg. from the comparison star. The result of Struve's labours seemed to indicate that the parallax of 61 Cygni was half a second.

Considerable doubt existed as to which result was the correct one. Auwers,[1] on a discussion of the whole question, was inclined to agree with Struve, and it was with the view of settling the difference that Dr. Brünnow commenced the work. It had, however, been but little more than commenced when Dr. Brünnow resigned his position at Dunsink, and on me, as his successor, devolved the task of continuing and completing the work. A first instalment of the Observations, and a discussion of the result, has been already given in Part III., *Dunsink Observations*. I now give a further instalment, completing the observations made by myself. The final discussion of the entire series, which amalgamates Dr. Brünnow's work and my own, must be postponed until the publication of Part V. of *Dunsink Observations*.

Dr. Brünnow employed the star BD + 38°, 4351, 9·5 mag., for the comparison. On 31st March, 1878, I found that this star followed 61 (A) Cygni in 51ˢ·5 and 66″·5, north. Brünnow had ascertained that the measurement of difference of declination could be made with extreme accuracy by the South equatorial, and consequently it was the method of differences of declination that he employed. The first series of observations were made with 61 (A) Cygni, and from them I deduced a parallax of 0″·4654, practically agreeing with Struve's result. See *Dunsink Observations*, Part III., pp. 16–40.

In the series now under discussion I employed the *following* star 61 (B) Cygni, which had then moved into the position marked 1878 on the figure.. This series was commenced on 18th September, 1878, and concluded on 2nd October, 1879.

On each night of observation it was usual to take four complete measures of the difference of declination. Each complete measure was derived from four readings of the screws, followed by four after the wires had been crossed. The final result adopted for each night was the mean of the four complete measures.

To illustrate the nature of these observations, and the method employed in their reduction, I here give the series of measures taken on the 16th November, 1878, a date which I have selected at random.

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[1] *Abhandlungen* der Akademie zu Berlin, 1868.

Micrometric Measurements of the Difference of Declination between 61 (B) Cygni *and* BD + 38°, 4351, *on* 16*th November*, 1878.

Screw I.	Screw II.	Screw I.	Screw II.	Screw I.	Screw II.	Screw I.	Screw II.
63698	40627	55783	32139	64318	40047	55599	32446
63753	40598	55857	32134	64163	40177	55562	32506
63791	40537	55902	32063	64175	40237	55501	32549
63823	40537	55921	32074	64097	40257	55483	32633
55639	32356	64217	40184	55906	32143	63557	40863
55666	32353	64215	40142	55697	32293	63293	41103
55732	32268	64202	40113	55716	32303	63267	41088
55753	32262	64213	40095	55708	32348	63154	41228

Each of these eight columns had first to be reduced to seconds. This is accomplished by adding together the four larger numbers in each column, and subtracting from the result the sum of the four smaller numbers. *E. g.* for the first column this result is 32·275. This has to be multiplied by one-eighth of the value of the micrometer Screw I., at the temperature of the instrument (39°·9). The result thus found is 36″·292. In a similar manner the movement of Screw II. in the second column gives 37″·224. Thus the first set of measures on the night in question gives for the apparent total distance the result 73″·516. This must, however, receive a correction of + 0″·026 on account of refraction, and of – 0″·031 on account of reduction for aberration, precession, and nutation, so that the final result is 73″·511. In a similar manner we have for each of the other sets of observations on the night in question 73″·705, 73″·539, 73″·453. The mean of the whole four is 73″·552, which is accordingly taken as the final result of the observations for this one night.

In many cases the number of complete measures was less than four, so it has been found convenient, when estimating the weight attached to each night's work, to use the number of complete measures which have been obtained. Thus, for the night just considered, the weight is taken as 4.

The following Table contains the mean results of the observations on the several nights which are included in the present series :—

Mean Results of the Observations of the Difference in Declination between 61 (B) Cygni *and* BD + 38°, 4351, *reduced for Refraction and Reduction.*

Date.	Difference.	Date.	Difference.	Date.	Difference.
1878.		1879.		1879.	
Sept. 18,	73″·657	Nov. 17,	73″·609	April 30,	72″·117
,, 20,	73 ·633	,, 21,	73 ·507	May 4,	72 ·229
,, 23,	73 ·579	,, 25.	73 ·615	,, 8,	71 ·907
,, 25,	73 ·613	,, 28,	73 ·437	,, 15,	71 ·602
Oct. 13,	73 ·520	Dec. 1,	73 ·554	,, 22,	71 ·640
,, 24,	73 ·698	,, 5,	73 ·436	June 10,	71 ·530
,, 25,	73 ·528	,, 8,	73 ·442	,, 15,	71 ·345
,, 28,	73 ·739	,, 30,	73 ·268	,, 28,	71 ·169
,, 29,	73 ·537	1879. Jan. 8,	73 ·400	July 26,	70 ·853
,, 31,	73 ·707	,, 15,	73 ·370	Sept. 17,	70 ·424
Nov. 1,	73 ·802	,, 18,	73 ·325	Oct. 2,	70 ·816
,, 8,	73 ·633	April 10,	72 ·512		
,, 16,	73 ·552	,, 16,	72 ·348		

A glance at these results exhibits, in a conspicuous manner, the large proper motion of 61 (B) Cygni relatively to the star which has been chosen for comparison. To clear the observations from the grosser part of the effects of proper motion, it became necessary to adopt an approximate value of the relative annual proper motion in declination. The former series of observations had conclusively established the fact that the comparison star is not affected by any considerable proper motion. I therefore felt warranted in assuming Argelander's value of the absolute proper motion of 61 B Cygni in declination as approximately the relative proper motion. The value in question is + 3″·016 (*Positiones Mediæ*, p. 27).

The mean epoch of the entire series of observations is 1879·069. The mean value of the observed differences of declination is 72″·85549. The assumed epoch is 1879·0, whence, applying a correction of + ·20865 for proper motion, we have as the adopted mean difference of declinations at the epoch 73″·06414.

The equations of condition are now formed in the usual manner.

The true mean distance at the epoch is assumed to be $73''{\cdot}06414 - x$; the true value of the proper motion in declination is assumed to be $3''{\cdot}016 + x'$; the correction to be applied to an observed difference of declination for parallax ϖ is $-[9{\cdot}92229]\cos(\odot - 121^\circ\ 39')R\varpi$. The correction to be applied for a possible difference κ between the coefficients of aberration of the two stars is $-[9{\cdot}92229]\sin(\odot - 121^\circ\ 39')\kappa$.

Solving the equations, I obtain

$$x = +\ 0''{\cdot}0227 \pm 0''{\cdot}0194,$$
$$x' = -\ 0''{\cdot}0878 \pm 0''{\cdot}0705,$$
$$\varpi = +\ 0''{\cdot}4676 \pm 0''{\cdot}0321,$$
$$\kappa = +\ 0''{\cdot}0719 \pm 0''{\cdot}0314.$$

The sum of the squares of the absolute terms is 6·172, while the sum of the squares of the residuals is but 1·223, the weights being of course taken into account in each case.

The probable error of one observation is $\pm\ 0''{\cdot}1298$, whence the

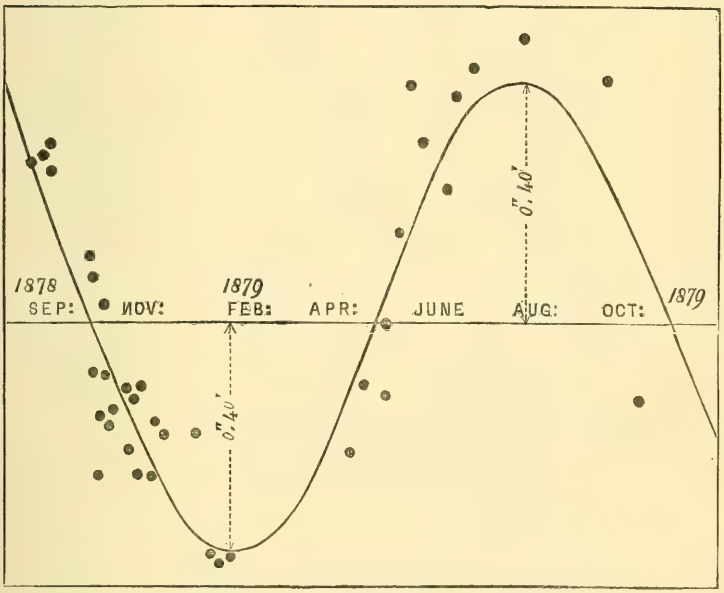


Fig. 2.—Parallax in Declination of 61 (B) Cygni. Ordinates indicate Parallax of 0″·47. Dots indicate Observations.

probable error of the mean of four observations which form a complete series for one night is $\pm\ 0''{\cdot}0649$.

The agreement of the present parallax of $0''{\cdot}4676$ with that of

0″·4654, found by the former series, is very satisfactory. The accordance is indeed so close that there can be no doubt it is to some extent due to the chapter of accidents. These investigations confirm the supposition that the annual parallax of 61 Cygni is nearer the half second found by Struve than the third of a second found by Bessel.

In order to show the degree of accuracy which can be expected in such observations, I give a diagram (Fig. 2) which represents the present series of observations on the assumption of a parallax of 0″·4676. The effect of such a parallax on the difference of declinations cannot exceed 0″·40. The dots denote the observations, and the curve gives the calculated effect of parallax.

Though some of the discrepancies seem large, relatively to the total amount to be measured, yet the greatest divergence of the observation from the curve is not more than the angle subtended by a penny-piece at the distance of fifteen or twenty miles.

(P III 242.)

In the *Monthly Notices*, vol. xx. p. 8, is a Paper by O. Struve, "On a star which would be suitable for a parallax series." The star in question is P III 242, its position for 1879·0 being $\alpha = 3^h\ 59^m\ 30^s$, and $\delta = 37°\ 45'·3$. Argelander, in his Catalogue of 560 stars, had pointed out that P III 242 probably formed a wide Binary system with the next following star of his Catalogue 50 Persei, on account of the equality in direction and quantity of their large proper motions.

Struve remarks also that P III 242 is a double star of Herschel's first class (No. 531 of O. Struve's Catalogue), the components being of $6·7^{th}$ and $8·9^{th}$ magnitudes respectively, and 3″ or 4″ distant. The physical correction of the two components of P III 242 appears to be established by their equal proper motions. A fourth star (BD + 37°, 877, mag. 7·8) is south, preceding P III 242 at a distance of nearly 4′. This star does not belong to the system formed by P III 242 and 50 Persei, for the changes in its position with respect to P III 242 correspond exactly to the proper motion of the latter. "This star, therefore" (says Struve, in conclusion) "would be a very qualified object of comparison for determining the relative parallax of P III 242, for which a considerable amount is indicated by the proper motion, and by the probable physical connexion with 50 Persei at 15′ distance."

Additional interest arises from Mr. Burnham's discovery that BD + 37°, 877, is also a double star, the distance being 1″. See *M. A. S.*, vol. XLIV. p. 158.

So far as I know, no measures have hitherto been made with the view of testing whether Struve's surmise as to the existence of a parallax for P III 242 could be substantiated. I therefore commenced a series of observations in January, 1879, of the distance and position of the comparison star which Struve suggested, from the larger star of the pair P III 242.

In an important feature, however, the observations now to be discussed are very different from those which had previously been made

with our micrometer. The distance in this was no less than 237″ ±, which is greatly in excess of the distances measured in the regular series of parallax observations contained in our previous publications. Had there been any suitable companion star nearer to P III 242, I should certainly have preferred it, for the distance 237″ is too great to be measured by our micrometer with the accuracy which can be attained when the distance is only about one or two minutes. From this cause the results of the observations are not so satisfactory as I would wish, though they are quite sufficient to show that P III 242 has no considerable parallax.

The following are the observations which I have made of the distance and position corrected for refraction, and reduced to the mean places of the stars at the epoch 1879·0 :—

P III 242.

Distance and Position of BD + 37°, 877 *from* P III 242.

Date.	Distance.	Position.	Date.	Distance.	Position.
1879.			1879.		
Jan. 11,	237″·558	207° 17′·35	Oct. 5,	237″·203	207° 17′·28
Feb. 7,	237 ·529	207 23 ·47	,, 17,	237 ·497	207 16 ·14
,, 19,	237 ·074	207 13 ·16	,, 25,	237 ·315	207 17 ·12
,, 22,	237 ·174	207 16 ·04	,, 25,	237 ·049	207 22 ·83
,, 23,	237 ·695	207 10 ·25	Nov. 1,	236 ·965	207 8 ·40
,, 25,	237 ·348	207 16 ·96	,, 2,	237 ·305	207 17 ·66
March 1,	237 ·220	207 9 ·08	,, 8,	237 ·041	207 19 ·72
,, 19,	237 ·605	207 15 ·99	,, 8,	237 ·423	207 21 ·57
April 4,	237 ·422	207 9 ·27	,, 11,	237 ·588	207 12 ·86
,, 6,	—	207 14 ·00	Dec. 3,	237 ·647	206 59 ·53
,, 10,	237 ·495	207 15 ·66	,, 5,	237 ·186	207 5 ·91
Aug. 14,	237 ·268	207 19 ·18	,, 17,	237 ·587	207 25 ·42
,, 22,	236 ·973	207 8 ·47	,, 18,	237 ·215	207 29 ·27
,, 23,	237 ·177	207 12 ·83	,, 24,	237 ·130	207 22 ·88
Sept. 17,	237 ·242	207 16 ·28	1880.		
Oct. 4,	237 ·151	207 20 ·24	Jan. 9,	236 ·715	207 20 ·66

According to O. Struve (*loc. cit.*), the annual proper motion in right ascension is + 0^s·0167, and the declination – 0″·152. It hence appears that the arc moved over in one year by P III 242 is 0″·2497, while the position angle of the star, in the position it will occupy next year, measured from the present position, is 127°·5. The correction to be applied to the observed distance, in order to reduce the observed distance to that between the places at the epoch, is 0″·04407 per annum, while the corresponding correction to the observed position angle is – 3′·565, or in arc – 0″·2457.

The adopted mean distance at the epoch is 237″·320, and the adopted mean position is 207° 13′·86.

From the usual formulæ it is found that when $\odot$ is the sun's longitude, R the sun's radius vector, and π the annual parallax of P III 242, the correction to be applied to the observed distance to clear it from the effects of parallax is

$$-[9{\cdot}82787]\,\varpi R\cos(\odot - 174^\circ\ 56'\ 0''),$$

while the corresponding correction for the observed position angle is

$$-[9{\cdot}90007]\,\varpi R\cos(\odot - 142^\circ\ 8'\ 29'').$$

Assuming that x is the correction to be applied to the annual mean distance, while x' is the correction to the assumed value of the proper motion in distance, and κ is a probable difference in the coefficients of aberration of the stars, then we have from the observations of the distance the usual equations of condition.

Solving these, we deduce in the usual way

$$x = -\,0''{\cdot}1459 \pm 0''{\cdot}08,$$
$$x' = +\,0''{\cdot}3009 \pm 0''{\cdot}15,$$
$$\varpi = +\,0''{\cdot}0163 \pm 0''{\cdot}09,$$
$$\kappa = +\,0''{\cdot}1405 \pm 0''{\cdot}12.$$

The sum of the squares of the residuals is 1·2732, from which the probable error of one complete observation is ± 0″·15. The sum of the squares of the absolute terms is 1·4638.

We next proceed to form the equations of condition from the observations of the position angle. In a complete series of measures, four observations of the parallel and four of the position angle have been made. Owing to the great distance of the stars, the measurements of the position angle (estimated in arc) are not very satisfactory; and on two occasions (3rd December and 5th December, 1879) the discrepancies have attained to very undesirable dimensions. The residual on 3rd December is no less than – 1″·332, but only a weight of one-half attaches to this result because it was based on but two observations of the parallel and two of the position. The notes at the time of

observation are, "snow and severe frost; low and hazy, but tolerably steady." On the next night of observation, December 5th, the number of observations was complete, and they were fairly accordant: the notes at the time record, "good definition; thaw; occasional clouds:" the residual on this occasion is − 0″·895. It will be noticed that these observations occur at dates when the parallax produces but very little effect, the coefficient being + ·2536 on the first occasion, and + ·2801 on the second. From these we obtain

$$x = + 0''{\cdot}0185 \pm 0''{\cdot}14,$$

$$x' = + 0''{\cdot}0076 \pm 0''{\cdot}27,$$

$$\varpi = - 0''{\cdot}1371 \pm 0''{\cdot}11,$$

$$\kappa = + 0''{\cdot}1420 \pm 0''{\cdot}18.$$

The sum of the squares of the absolute terms of the equations is + 4·3105, and the sum of the squares of the residuals is + 4·1077, from whence the probable error in an arc of one complete observation of the position angle is

$$\pm 0''{\cdot}263$$

If we combine the two values of the parallax, making due allowance for the weights, we obtain, as the final result of this series of observations,

$$\varpi = - 0''{\cdot}045 \pm 0{\cdot}070.$$

If this result were to be strictly interpreted, it would mean that the comparison star was actually the more distant of the two. Observing, however, that the probable error is greater than the parallax itself, it would seem unsafe to draw any conclusion from these observations, save that the difference between the parallaxes of P III 242 and BD + 37° 877 is too small to be measured with accuracy.

GROOMBRIDGE 1618.

This star is No. 89 of Argelander's list of stars, with large proper motion (Bonn, *Obs.*, vol. vii. p. 69). It is + 50°, 1725 in the *Duchmusterung*, where its magnitude is given as 6·8. The position of the star at the epoch 1878·0 is found from meridian observations at Washington in 1871, and Radcliffe observations in 1859, to be R. A. = $10^h\ 3^m\ 53^s{\cdot}73$, $\delta = 50°\ 4'\ 13''{\cdot}9$, allowance having been made for the proper motions.

According to Argelander (*l. c.* p. 110) the proper motion in R. A. is − 0ˢ·1390, and in Decl. − 0″·501. This corresponds to an arcual proper motion of 1″·429 per annum, the position angle being 249° 29′, *i. e.*, this is the position angle of the place of the star next year from the present place.

The distance and position of the adjacent star + 50°, 1724 (8·8 mag.) has been measured with the view of ascertaining the parallax

of Gr. 1618. It will at the outset be of importance to show that the comparison star has not a proper motion comparable in magnitude with that of Gr. 1618.

This will appear most clearly by a comparison of the recent observations with those made by Argelander on March 21st, 1843, as reduced in Argelander-Oeltzen to the epoch 1842·0. From an approximate reduction of my observations I conclude that at the epoch 1878·0 the distance of + 50°, 1724 from Gr. 1618 is 198″·1, and the position angle is 201° 42′·8. From this I find

$$\Delta\alpha = 7^{s}\cdot 603,$$

$$\Delta\delta = 184''\cdot 1\ ;$$

but from Argelander-Oeltzen, we have

$$\Delta\alpha = 12^{s}\cdot 4,$$

$$\Delta\delta = 203''\cdot 9.$$

We apply to these differences the annual proper motion of Gr. 1618, viz. – 0^{s}·1390 in R. A. and – 0″·501 in Decl. During the thirty-five years that have elapsed since Argelander's observations the corrections will amount to – 4^{s}·87 and – 17″·5, respectively. We thus find for the values in 1878

$$\Delta\alpha = 7^{s}\cdot 5,$$

$$\Delta\delta = 186''\cdot 4.$$

It is therefore evident that + 50°, 1724 cannot have a proper motion which even in thirty-five years amounts to much more than 0^{s}·103 R. A., or 2″·3 in Declination. Compared with the large proper motion of Gr. 1618 these quantities are inappreciable. We may, therefore, conclude as a first approximation that the absolute proper motion assigned by Argelander to Gr. 1618 coincides with its proper motion relatively to the comparison star + 50°, 1724.

The annual decrement of the distance from Gr. 1618 to + 50°, 1724, in consequence of the proper motion of the former, is 0″·9579. The position angle decreases for the same reason at the rate of 18′·398 annually.

In the first series of observations now to be discussed, measurements were made on fifty-five nights both of distance and position. In the present Paper the measurements of the distance alone are discussed.

The following Table contains the observations of the distance, corrected in the usual manner, for the effects of refraction and temperature of the micrometer screw, and reduced to the epoch 1878·0. The corrections for proper motion have, however, not yet been applied.

GROOMBRIDGE 1618, I.

Corrected Distance of + 50°, 1724 *from* Gr. 1618.

Date.	Distance.	Date.	Distance.	Date.	Distance.
1878.		1878.		1878.	
March 4,	198″·381	April 24,	198″·507	Sept. 25,	198″·029
,, 13,	198 ·542	,, 27,	198 ·261	Oct. 24,	197 ·830
,, 13,	198 ·459	May 3,	198 ·327	,, 28,	198 ·195
,, 15,	198 ·370	,, 5,	198 ·382	Nov. 1,	197 ·858
,, 18,	198 ·484	,, 9,	198 ·741	,, 8,	197 ·970
,, 18,	198 ·581	,, 18,	198 ·355	,, 17,	197 ·799
,, 21,	198 ·537	,, 20,	198 ·492	,, 19,	197 ·949
,, 21,	198 ·499	,, 21,	198 ·364	,, 25,	198 ·059
,, 22,	198 ·450	,, 28,	198 ·232	,, 28,	198 ·105
,, 24,	198 ·783	July 1,	198 ·330	Dec. 1,	198 ·303
,, 24,	198 ·753	,, 7,	197 ·951	,, 5,	198 ·063
,, 25,	198 ·484	,, 8,	197 ·812	,, 8,	198 ·337
,, 29,	198 ·493	,, 12,	197 ·806	1879. Jan. 8,	198 ·088
,, 29,	198 ·605	,, 21,	197 ·743	Feb. 5,	197 ·958
,, 31,	198 ·445	,, 28,	197 ·795	,, 22,	197 ·993
,, 31,	198 ·460	,, 30,	197 ·999	,, 25,	198 ·142
April 1,	198 ·537	,, 31,	197 ·751	,, 28,	198 ·184
,, 1,	198 ·493	August 2,	197 ·892	March 19,	198 ·213
,, 6,	198 ·461	,, 10,	198 ·047	,, 31,	197 ·819
,, 17,	198 ·353	Sept. 20,	197 ·869	April 2,	197 ·578
,, 21,	198 ·415	,, 23,	198 ·221		

From these, I conclude in the usual manner,

$$x = -0''\cdot1621 \pm \cdot05$$
$$x' = +0''\cdot1534 \pm \cdot07$$
$$\varpi = +0''\cdot3472 \pm \cdot05$$
$$\kappa = -0''\cdot2890 \pm \cdot06$$

The probable error of one complete observation is ± ·15.
The sum of the squares $(nn) = 3{\cdot}537$.
The sum of the squares $(vv) = 2{\cdot}935$.

The result of the observations is therefore to indicate a parallax of about one-third of a second for Gr. 1618. Though the probable error of the result is only 0″·05, yet there were certain features which seemed to me to require further examination. The signs of the residuals look as if some systematic irregularity had affected the measures. The large value of the unknown κ seems also somewhat improbable. The substitution of the values for the unknowns only abates the sum of the squares of the absolute terms from 3·5373 to 2·935. I therefore decided to commence another series of observations, in the hope that the experience already obtained would ensure a better result.

GROOMBRIDGE 1618, II.

Corrected Distances of + 50°, 1724 *from* Gr. 1618.

Date.	Distance.	Date.	Distance.	Date.	Distance.
1879.		1880.		1880.	
Aug. 14,	197″·187	Mar. 12,	196″·473	April 25,	196″·629
,, 23,	196 ·846	,, 15,	196 ·398	,, 27,	196 ·589
Oct. 28,	197 ·184	,, 18,	196 ·170	May 6,	196 ·432
Nov. 1,	196 ·935	,, 19,	196 ·577	,, 7,	196 ·255
,, 11,	197 ·079	,, 19,	196 ·524	,, 8,	196 ·317
,, 13,	196 ·841	,, 20,	196 ·862	,, 13,	196 ·466
,, 30,	197 ·228	,, 21,	196 ·557	,, 15,	196 ·319
Dec. 4,	197 ·056	,, 21,	196 ·489	,, 16,	196 ·577
,, 10,	197 ·177	,, 22,	196 ·545	July 15,	196 ·191
,, 17,	196 ·970	,, 22,	196 ·626	,, 16,	195 ·807
,, 18,	196 ·817	,, 31,	196 ·924	,, 20,	196 ·009
1880.					
Jan. 9,	196 ·985	April 6,	196 ·452	,, 21,	195 ·748
,, 21,	196 ·961	,, 8,	196 ·583	,, 21,	195 ·852
Feb. 4,	197 ·077	,, 22,	196 ·517	,, 29,	195 ·757
,, 5,	196 ·985	,, 24,	196 ·583		

From these we find the following values:—

$$x = -0''\cdot3532 \pm \cdot133,$$

$$x' = +0''\cdot3222 \pm \cdot116,$$

$$\varpi = +0''\cdot3196 \pm \cdot052,$$

$$\kappa = -0''\cdot0422 \pm \cdot066.$$

The probable error of one observation is ± ·119.
The sum of the squares $(nn) = 2\cdot330$.
The sum of the squares $(vv) = 1\cdot255$.

These observations are free from the features which appeared to me to be objectionable in the former series. On the other hand, it is to be observed that the corrections to the proper motion and to the annual mean distance now attain considerable amounts. This is, I believe, partly due to the choice of an epoch which is more than a year from the mean date of the observations. To examine the plausibility of these corrections I have combined the results of the two series of observations, taking account of their probable errors. I thus find

$$x = -0''.1858 \pm \cdot047,$$

$$x' = +0''\cdot1985 \pm \cdot060,$$

$$\varpi = +0''\cdot3339 \pm \cdot036,$$

$$\kappa = -0''\cdot1774 \pm \cdot044.$$

These results do not appear to be at all improbable. A positive correction to the proper motion is indeed indicated by the adopted mean distances at the epochs of 1878 and 1879. These are, respectively, 190·7608 and 197·7308. This corresponds to a proper motion in the distance of somewhat over a second per annum, while the assumed proper motion is somewhat less than a second. Nearly half of the value of x' is thus accounted for.

I believe that these observations render the existence of a parallax of about one-third of a second tolerably certain. It will not, however, be possible to determine the parallax definitively until further investigations have been made. Measurements of the position angle of the comparison star from Gr. 1618 are very well adapted for this purpose. Indeed, the parallax has a much larger effect upon the position angle than it has upon the distance. I have made such measurements at the same time as the measurements of distance which are here discussed. These observations are not yet ready for publication. I may, however, say that though some difficulties have been met with, yet the position angle observations, as a whole, tend to confirm the fact that Gr. 1618 has a parallax sufficiently large to entitle it to a place among the sun's nearest neighbours.

LX.—Report on the Flora of the Blasket Islands, Co. Kerry. By Richard M. Barrington, M.A., LL.B.

[Read, February 14, 1881.]

The group of islands known as the Blaskets lie to the west of Dingle promontory, Co. Kerry, and their geology and position show that they are but a prolongation of its ridge. They are interesting, as being the most westerly land in Europe, if we except the Azores. They lie west of 10° 30′ west longitude, and immediately north of the 52nd parallel of latitude. Counting rocks which rise little above high-water mark, they number 109 islands, but six only are worthy of the name, the rest being devoid of vegetation, with one or two exceptions. The six largest islands are :—

	Acreage.	Highest point in feet.	Population.
Great Blasket, - - -	1020	961	130
Innishtooskert, - - -	186	573	Uninhabited.
Innishvicillane, - - -	171	453	One family.
Innishnabro, - - -	102	583	Uninhabited.
Tearaght, - - - -	47	602	The light-house keepers.
Beginish, - - - -	32	57	Uninhabited.

A circle having a diameter of eight miles would include all the Blaskets, except a few rocks.

No botanist having ever examined this remote group with care, I made an effort to explore them in June, 1879. Having reached the town of Dingle, which is nine miles from the extreme west of the promontory, the police informed me that an unsuccessful attempt had recently been made to serve processes on the Blasket Islanders, and that they were hostile to strangers. This proved to be correct, and I found considerable difficulty in landing. At Dunquin, a small village on the mainland, opposite the Great Blasket, the boatmen declined to row me across. I heard subsequently they suspected I was a police-man in plain clothes. All sorts of excuses were made. Finally, after

four days' waiting, I procured a boat, the Rev. Father Egan, P.P., having spoken to the people on my behalf.

On approaching the Great Blasket, which is one mile distant from the nearest point of the mainland, the people were seen to run from the houses, and congregate on the edge of the cliff over the landing-place, shouting and gesticulating at the same time. Heaps of stones were piled, and the natives began to throw them at our boat.

Much loud conversation took place, which lasted a considerable time. In the end I was permitted to land, provided I kept at a distance from the houses. Seeing no harm was intended, the inhabitants became friendly, and many of them accompanied me during a walk of three hours, which I then took over the island. Unfavourable weather and want of time did not permit a longer visit in 1879, but I saw sufficient to make me anxious to examine the flora of the islands carefully, which could not be done without a stay of some days on the Great Blasket.

The Royal Irish Academy having given me a grant to explore the group, I again went to Dingle in July, 1880. No difficulty was now experienced in procuring boats. On the contrary, the people received me with many expressions of welcome, as I had interested myself on their behalf during the severe distress in the spring.

I landed on July 16. The mud cabins are of the poorest description. I slung my hammock from the rafters of a vacant one, called the schoolhouse. The curiosity of the natives was intense, and I suffered much from intruders when examining specimens, and placing them between the blotting sheets.

The houses on the Great Blasket are all built together on the end facing the mainland. Here the people have several patches of potatoes and oats, the only crops noticed. The rest of the island is pasture, and is grazed by cattle, sheep, and goats. There are no lakes, or even pools, on any of the Blaskets. The Great Blasket is three and a-half miles long by half a mile broad. Its longest axis extends in a south-westerly direction. In shape it resembles a ridge, for the most part 700 feet high, and for a mile its height exceeds 900 feet. Towards the south the ridge slopes much more gradually than on the northern face, which is almost perpendicular in many places.

The Great Blasket and Innishnabro consist of the Dingle beds, which are placed by Mr. Jukes between the Upper Silurian and Old Red Sandstone. Generally the Blasket group is Silurian, but trap rocks appear on Beginish and Innishvicillane. Near Dunquin the Dingle beds consist of green and purple grits and slates without fossils, and pass up into coarse Sandstones. Old Red Sandstone appears on the extreme north point of Innishtooskert. The conical Tearaght is composed of grits and conglomerates.

The cliffs and precipices are very grand, notably the north-western face of the Great Blasket and the north-eastern portion of Innishnabro, which latter resembles, when viewed from the sea, a cathedral 500 feet high, the towers, spires, and even doors and

windows, being represented.[1] Innishtooskert, has an isolated pinnacle of rock, with a great chasm in the cliff near it, scarcely less striking. The Tearaght is like a black tooth projecting from the ocean, its sides being rocky, desolate, and very barren. The landing is here effected with difficulty, even in calm weather. Myriads of sea-fowl, especially Puffins, swarm on the ledges of this distant island, which is nine miles from the mainland.

I observed that the cliffs on the northern face of all the islands were rather more productive in species than those on the south side. This is especially the case with the Great Blasket, and may in part be attributed to the greater frequency and violence of south and south-westerly winds, which in exposed situations would, doubtless, have an injurious influence on the growth of plants.

On the northern cliffs of the Great Blasket I noticed *Luzula sylvatica* plentiful, *Scilla nutans* and *Hymenophyllum unilaterale:* these are not found on any other island on the west coast of Ireland that I am aware of. *Primula vulgaris, Valeriana officinalis, Lychnis flos-cuculi, Viola sylvatica, Cardamine pratensis,* and other plants may be gathered here also, giving the vegetation an inland appearance. It is not usual to find such species associated on the face of a marine precipice exposed to the storms of the Atlantic.

Next to the Great Blasket, Innishvicillane is certainly the most fertile in species. Some cultivation exists here, and one family resides. Innishtooskert, though the largest of the group, except the Great Blasket, is the most barren island, for its size, I have visited on the west coast. It is uninhabited, and closely cropped by sheep. On the uninhabited island of Innishnabro I gathered *Lavatera arborea,* one or two conspicuous specimens growing on the cliff near the landing place. On the Tearaght Lavatera also grows. I noticed several plants growing on various parts of the rock. The fact of the lighthouse being on the Tearaght leaves room to question the nativity of Lavatera here. It may have been introduced by the keepers at one time. The occurrence of this species in suspicious localities along our coasts induces me to prefix a mark of doubt. If, however, Lavatera is anywhere indigenous in Ireland, it is probably on the Blaskets.

The late Mr. W. Andrews, in his numerous Papers in the Dublin Natural History Society's Proceedings, which refer principally to zoology, here and there notices some plants which occur on the Blasket Islands, viz., "a very fine species" of *Saxifraga geum,* "remarkable in having a series of glands of a rich rose-colour surrounding the base of the ovary, which give a remarkable appearance to its inflorescence." This form, Mr. Andrews states, he found at the extreme western point of the Great Blasket.[2]

I did not meet with any form of *Saxifraga geum* on the Blaskets,

[1] See illustration in Mr. Andrews' "On the Sea Fisheries of Ireland."

[2] *Proceedings, Dub. Nat. Hist. Soc.*, vol. vi., part i., p. 85.

but I gathered strong and luxuriant specimens of *Sax. umbrosa* on the northern cliffs of the large island. At the entrance to Dingle Harbour Mr. A. G. More informs me he has gathered large and strong forms of *Sax. geum*. *Saxifraga umbrosa* was not observed on the southern side of either Innishvicillane, Innishtooskert, or the Great Blasket—the three islands on which it was noticed.

Hymenophyllum unilaterale (*Wilsoni*) Mr. Andrews met with on the Great Blasket "in rich abundance."[3] It can scarcely be called abundant, seeing that I only gathered it in one spot on the northern cliffs of the island.

Roccella fuciformis, a very rare and local lichen, is recorded by Mr. Andrews from the Tearaght Rock.[4] The late Dr. David Moore always considered that a large form of *Ramalina scopulorum* had been mistaken for it.[5] It is much to be wished that some competent cryptogamic botanist should visit the Tearaght, and set the matter at rest.

Cerastium arvense, var. *Andrewsii* (Syme), was also gathered by Mr. Andrews on the Blaskets. This variety I noticed in tolerable plenty on Innishvicillane, Innishnabro, and the Great Blasket, and it is the only form which occurs.

The occurrence of Lavatera has been already referred to. It appears to have escaped Mr. Andrews' attention.

Suaeda maritima, a species classed by Mr. Watson, in his Cybele Britannica, under the littoral zone, grow on the Tearaght between 400 and 500 feet above the sea-level. It occurs on the rocky face of the cliffs, and I did not gather it on any of the other islands. The waves around the Tearaght rise so high, that no plants can grow much below 150 to 200 feet.

Euphrasia officinalis does not assume that stunted form, with thick fleshy bracts and leaves packed close together, which I have noticed on the Islands Achill, Boffin, and Tory, in Ireland, and Staffa, in Scotland. The Blasket specimens are small, but the leaves and bracts are not broader than is usual in the inland form, and they are not succulent.

While examining the flora of the Blaskets, I took the opportunity of visiting the Skellig Rocks, twenty miles to the south, the only Irish breeding-place of the Gannet, and gathered twenty-three species on the Great Skellig. Here I observed a luxuriant form of *Cochlearia officinalis*, with large and strongly-reticulated pods. On the other hand, a variety of the same species, approaching var. *alpina* (Bab.), was gathered on the Great Blasket.

Landing on the Blaskets on Friday, July 16th, I left on the following Tuesday afternoon, having visited all the islands, except Beginish, which is flat and small in area, and of little interest. Alto-

[3] *Proceedings, Dub. Nat. Hist. Soc.*, vol. ii. p. 173.
[4] *Proceedings, Dub. Nat. Hist. Soc.*, vol. i. p. 82.
[5] *Fide* Mr. A. G. More, who discovered *Roccella tinctoria* in the Isle of Wight.

gether 174 species, according to the London Catalogue of British Plants, 7th edition, were gathered, and specimens of most of them dried for examination. This includes *Spergularia rupestris*, a very common coast species, which I gathered only on the Skelligs, and which was probably overlooked on the Blaskets. Of the 174 species, 162 were noticed on the Great Blasket. The other islands were examined only with a view to detect species not noticed on the largest island, and the list of species for each is incomplete. Innishtooskert is so barren that it is seldom referred to in my list, and I have not indicated it by a separate letter, as in the case of the other islands.

Five distinct groups of islands have now been examined on the west coast of Ireland. Professor E. P. Wright, in 1866, and Mr. H. C. Hart in 1869,[6] visited the Arran Islands, in Galway Bay.[7] Mr. A. G. More, in 1875, visited with me Bofin Island, county Mayo.[8] Tory Island, county Donegal, was visited in 1877 by myself;[9] and Mr. H. C. Hart, in 1879, visited Aran Island, county Donegal.[10]

We may now add the Blasket Islands to the number; and as these local lists are valuable, not only for the sake of comparison with the portions of the mainland respectively opposite each island, but also with each other, I have thought it desirable now that we have five groups to compare for the first time, to draw out in a tabular form a list of species which shows at a glance all the plants which have been recorded from the five groups, as well as the islands on which they occur, and from which they are absent.

The areas of the five groups, with the number of species recorded from (and compared with each other) peculiar species, are:—

	Acres.	Total species.	Peculiar species.
Arran Islands, Galway . .	10781	372	130
Aran Island, Donegal, . .	4355	232	23
Innishbofin, ...	2312	303	36
The Blasket Islands, . .	1560	174	8
Tory Island, ...	785	145	1

[6] "Notes on the Flora of the Islands of Arran," *Proceedings, Dub. Nat. Hist. Soc.*, vol. v. p. 96.

[7] *A List of Plants found on the Islands of Arran, Galway Bay.* Hodges, Foster, & Co. Dublin. 1875. And *Journal of Botany*, 1875, p. 111.

[8] *Proceedings, Royal Irish Academy*, 2nd series, vol. ii. (Science) p. 553; and *Journal of Botany*, 1876, p. 373.

[9] *Journal of Botany*, vol. viii. (new series) p. 263, September, 1879.

[10] *Journal of Botany*, vol. x. (new series) p. 19, January, 1881.

The eight species peculiar to the Blaskets, and which have not been observed on any of the other islands, are—

Cardamine sylvatica.	Luzula sylvatica.
Lychnis githago.	Carex disticha.
Stellaria graminea.	,, pilulifera.
Scilla nutans.	Hymenophyllum unilaterale.

The occurrence of *Luzula sylvatica* in abundance, and *Scilla nutans* in tolerable plenty on a marine cliff on the west coast, is certainly unusual. *Carex disticha* grows on the summit of the Great Blasket (Croaghmore), 961 feet.

That there should be 130 species on the Arran Islands, in Galway Bay, not recorded from any of the other groups, is due to its much larger and more diversified surface as well as its limestone formation.

There are only seventy-two species which occur on all the islands.

The following plants, observed on the Blaskets, belong to Mr. H. C. Watson's "Atlantic Type":—

Lavatera arborea.	Crithmum maritimum.
Sedum anglicum.	Scirpus Savii.
Cotyledon umbilicus.	Hymenophyllum unilaterale.
Saxifraga umbrosa.	Nephrodium æmulum.

One species, *Koeleria cristata*, is new to district No. 1 of the Cybele Hibernica.

Plants which elsewhere are certainly native appear to be introduced on the Blaskets, as they are confined to the cultivated ground or its neighbourhood.

Though scanty, the flora of the Blaskets is not without interest. The extreme westerly position of these islands and their situation off the coast of Kerry, with their genial climate and characteristic vegetation, make a list of their species useful, as affording materials for a comparison with the other island floras, which the tabular catalogue will, I trust, prove useful in facilitating.

LIST OF THE PLANTS FOUND ON THE BLASKET ISLANDS.

B after a species signifies Great Blasket; V, Innishvicillane; N, Innishnabro; T, Tearaght; S, Skelligs.

Those certainly introduced are marked *, those possibly introduced †, those probably ‡.

RANUNCULACEAE.

Ranunculus flammula (Linn.) B.

Ranunculus repens (Linn.) Not common. B. V.

FUMARIACEAE.

‡*Fumaria confusa* (Linn.) A colonist among crops. B.

CRUCIFERAE.

Cakile maritima (Scop.) On the small strand. B.
‡*Sinapis arvensis* (Linn.) B.
‡*Brassica napus* (Linn.) B. } Colonists in cultivated land.
Cardamine pratensis (Linn.) In one or two places on the north side. B.
Cardamine sylvatica (Link.) North side. B.
Cochlearia officinalis (Linn.) Very fine on the Great Skellig, the pods being large and much reticulated; on the other hand, a small form found on the Great Blasket approaches var. *alpina* (Bab.) B. S.
†*Capsella Bursa-pastoris* (Moench.) I believe introduced. B. V.

VIOLACEAE.

Viola palustris (Linn). Common. B. V.
Viola sylvatica (Fries.) Great Blasket, north side. B. N.

POLYGALACEAE.

Polygala vulgaris (Linn.) Common. B. V.
[*Polygala depressa* (Wender). I believed to have been gathered also, but no specimen was preserved].

CARYOPHYLLACEAE.

Silene maritima (With.) Common. B. S. V.
Lychnis Flos-cuculi (Linn.) Only seen on the north side on the Great Blasket. B. N.
**Lychnis Githago* (Lam.) Among corn; a colonist. B.
Cerastium tetrandrum (Curt.) Common. B. S. N. T.
Cerastium triviale (Link.) Common. B.
Cerastium arvense (Linn.) Var. *Andrewsii* (Syme). Common on the three islands, and the only form observed. B. V. N.
Stellaria media (With.) B. V.
Stellaria graminea (Linn.) Rare; only in one spot. B.
Honkeneja peploides (Ehrh.) Only on the strand. B.
Sagina maritima (Don.) Frequent. B. S.
Sagina procumbens (Linn). Common. B. V.
‡*Spergula arvensis* (Linn.) Among corn; the form without papillae on the seeds. B.

Spergularia neglecta (Kindb.) Rare. V.
Spergularia rupestris (Lebel.) I have no specimen from the Blaskets, but it may have been overlooked. S.

PORTULACACEAE.

Montia fontana (Linn.) Rare. B.

HYPERICACEAE.

Hypericum pulchrum (Linn.) North side. B.

MALVACEAE.

†*Lavatera arborea* (Linn.) This plant occurs only on Innishnabro and the Tearaght. The former island is uninhabited. Only one or two specimens were observed on Innishnabro; on the Tearaght several. It is such a doubtful native on our coasts that I have hesitated to admit it as indigenous even on these wild islands; but it may be so. N. T.

LINACEAE.

Radiola millegrana (Sm.) Very diminutive and difficult to find. I observed it only on the south side in one or two spots. B.

LEGUMINIFERAE.

Anthyllis vulneraria (Linn.) Not common. B. V.
‡*Trifolium pratense* (Linn). Probably introduced by cultivation. B.
Trifolium repens (Linn.) Common. B. S. N.
Lotus corniculatus (Linn.) Common. B. V.
Vicia Cracca (Linn.) Scarce. B.
Vicia sepium (Linn.) Not noticed on Great Blasket. V.
Lathyrus pratensis (Linn.) Uncommon. B.

ROSACEAE.

†*Alchemilla arvensis* (Scop.) Rare, and a doubtful native.
Potentilla Tormentilla (Schenk.) Plentiful. B. N.
Potentilla anserina (Linn.) Common. B. V.
Rubus discolor (W. & N.) There is but one diminutive bramble on the Great Skellig growing out of a crevice in the rock near the summit, 714 feet. It is well known to the light-keepers as the "only Blackberry on the Skelligs." There are two or three bushes on the Great Blasket and on Innishvicillane. Species supposed to be *R. discolor*, but not determined satisfactorily. B. V. S.

LYTHRACEAE.

Lythrum Salicaria (Linn.) Scarce. B.
Peplis Portula (Linn.) In one spot. V.

ONAGRACEAE.

Epilobium obscurum (Schreb.) Near the village. B.

HALORAGIACEAE.

Callitriche platycarpa (Kutz.) Common. B. V.

CRASSULACEAE.

Sedum anglicum (Huds.) On the Great Skellig this species is very abundant. On the S. W. face it forms dense mats several yards across, to the exclusion of every other plant, and when in full bloom the odour of the flowers is perceptible at a considerable distance in the direction of the wind. B. S. N.
Cotyledon Umbilicus (Linn.) Abundant. I did not see *Sedum Rhodiola*, which might have been expected. B. S. N.

SAXIFRAGACEAE.

Saxifraga umbrosa (Linn.) Common on the north cliffs of the Great Blasket. Sparingly on Innishvicillane cliffs, facing the Great Blasket. I did not meet with any form of *Saxifraga Geum*. (*See* observations, page 370.) B. V.

UMBELLIFERAE.

Hydrocotyle vulgaris (Linn.) Common. B. V.
Crithmum maritimum (Linn.) Scarce. B. V.
Angelica sylvestris (Linn.) As elsewhere on the west coast of Ireland and Scotland a characteristic plant of the cliffs, but not as plentiful as I have noticed it further north. B. V.
**Heracleum sphondylium* (Linn.) Only near houses. B.
Daucus Carota (Linn.) B.

ARALIACEAE.

Hedera Helix (Linn.) Only near the strand. No form approaching the Irish Ivy. B.

RUBIACEAE.

Galium verum (Linn.) Banks near the strand. B.
Galium saxatile (Linn.) Common. B.
‡*Galium Aparine* (Linn.) A colonist. B. V.

VALERIANACEAE.

Valeriana officinalis (Linn.) Only on the northern face in one spot with *Scilla nutans*. B.

COMPOSITAE.

Carduus lanceolatus (Linn.) Native, I believe. B. V.
†*Carduus arvensis* (Curt.) Possibly introduced. B.
Arctium intermedium (Lange.) B. V.
Centaurea nigra (Linn.) Probably not native on the Skelligs. B. S. V.
Matricaria inodora (Linn.) Var *maritima* (Bab.) B. S.
Achillea Millefolium (Linn.) Not common. B. V.
‡*Artemesia vulgaris* (Linn.) A colonist; near the houses. B.
Gnaphalium uliginosum (Linn.) B.
‡*Senecio vulgaris* (Linn.) Near a garden. V.
Senecio Jacobæa (Linn.) Plentiful on Innishnabro, forming yellow patches; growth stunted. B. N.
Bellis perennis (Linn.) B.
Solidago Virga-aurea (Linn.) B.
Tussilago Farfara (Linn.) B.
‡*Lapsana communis* (Linn.) Only near houses. B.
Hypochæris radicata (Linn.) Near the village. B.
Leontodon autumnalis (Linn.)
Leontodon autumnalis, var. *pratensis* (Syme.) } Both observed. B. V.
‡*Taraxacum officinale* (Wigg.) Near the cottage; not noticed on Great Blasket. V.
†*Sonchus oleraceus* (Linn.) B.
†*Sonchus asper* (Hoffm.) S. V.
‡*Sonchus arvensis* (Linn.) B. } All three perhaps introduced—the last a colonist among corn and potatoes.

CAMPANULACEAE.

Jasione montana (Linn.) Plentiful. B. S. V.

ERICACEAE.

Vaccinum Myrtillus (Linn.) Common on the northern face. B.
Erica Tetralix (Linn.) Not uncommon. B. V.
Erica cinerea (Linn.) Plentiful. B. N.
Calluna vulgaris (Salisb.) B. N.

GENTIANACEAE.

Erythræa Centaurium (Pers.) Pasture near the village. B.

SCROPHULARACEAE.

‡*Veronica polita* (Fries.) B. } Colonists, near houses and potato
†*Veronica arvensis* (Linn.) B. } gardens.
Veronica serpyllifolia (Linn.) Looks native. B.
Euphrasia officinalis (Linn.) Not the fleshy and compact form I have noticed on Achill Island, Mayo; and also on the Island of Staffa, Scotland. The specimens were, however, small. B. V.
†*Bartsia Odontites* (Huds.) B. V.
Pedicularis sylvatica (Linn.) Frequent. B.

LABIATAE.

Thymus Serpyllum (Fries.) Frequent. B. V.
Prunella vulgaris (Linn.) Common. B. V.
Stachys palustris (Linn.) B.
Galeopsis Tetrahit (Linn.) Roofs of thatched houses, &c. B.
‡*Lamium amplexicaule* (Linn.) B. } All colonists in potato gardens
‡*Lamium incisum* (Willd.) B. } and among corn; *L. amplexi-*
‡*Lamium purpureum* (Linn.) B. V. } *caule* rare.
Teucrium Scorodonia (Linn.) Thoroughly exposed on the slopes of the Great Blasket and Innishnabro to Atlantic storms. B. N.

BORAGINACEAE.

†*Myosotis arvensis* (Hoffm.) Near cultivation. B. V.

PRIMULACEAE.

Primula vulgaris (Huds.) On the cliffs of the Great Blasket only, growing in exposed situations. B.
Anagallis arvensis (Linn). Far from cultivation on the uninhabited island of Innishnabro. B. N.
Anagallis tenella (Linn.) Common. B. V.

PLUMBAGINACEAE.

Armeria maritima (Willd.) Common. B. S.

PLANTAGINACEAE.

‡*Plantago major* (Linn.) With *Trifolium pratense* in pastures; a doubtful native. B.

†*Plantago lanceolata* (Linn.) B. S. N.

Plantago maritima (Linn.) Strange to say this very common species is not marked off in my list as occurring on the Blaskets. It must be abundant, and I have therefore inserted it. B. S.

Plantago coronopus (Linn.) B. S.

CHENOPODIACEAE.

Suaeda maritima (Dum.) Only noticed on the Tearaght Rock, and at a considerable elevation, probably 400 feet above the sea, on the rocky face of the cliff. T.

Beta maritima (Linn.) Not seen on the Great Blasket; abundant on the Skelligs. S. N.

‡*Chenopodium album* (Linn.) Among crops. B.

‡*Atriplex angustifolia* (Sm.) As in Boffin, I did not meet with *A. hastata* (Linn.) B.

Atriplex Babingtonii (Woods.) On the high margins of the cliffs up to 400 feet above the sea. B. S. V.

POLYGONACEAE.

†*Rumex obtusifolius* (Auct.) B. V.

†*Rumex crispus* (Linn.) B.

Rumex Acetosa (Linn.) B. S. V. N.

Rumex Acetosella (Linn.) Very luxuriant on the northern face of the Great Blasket among sheltered rocks. B.

Polygonum aviculare (Linn.) B.

Polygonum Persicaria (Linn.) B. V.

EMPETRACEAE.

Empetrum nigrum (Linn.) In one place, about 700 feet above the sea on the northern cliffs. Procured only by dislodging the specimen with stones. B.

EUPHORBIACEAE.

‡*Euphorbia Helioscopia* (Linn.) Sparingly among crops. B.

Urticaceae.

**Urtica dioica* (Linn.) Only near houses, and on the borders of cultivated ground. B.

Orchidaceae.

Orchis maculata (Linn.) Rare—in one spot only on the southern slope. B.

Liliaceae.

Scilla nutans (Sm.) Only on the north side, growing among rocks on the cliffs, with *Primula vulgaris*, *Valeriana officinalis*, &c. B.

Juncaceae.

Luzula sylvatica (Beck.) Plentiful on the northern cliffs. B.
Luzula multiflora (Koch.) Common. B. N.
Juncus conglomeratus (Linn.) B. V.
Juncus lamprocarpus (Ehrh.) B.
Juncus supinus (Moench.) Common. B. V.
Juncus bufonius (Linn.) V.
Juncus squarrosus (Linn.) Hilly pastures. B.

Cyperaceae.

Scirpus setaceus (Linn.) Frequent. B.
Scirpus Savii (S. & M.) Less common. B.
Eriophorum angustifolium (Roth.) Frequent. B. V.
Carex disticha (Huds.) Only on the highest portion of the Great Blasket. B.
Carex stellulata (Good.) Common. B. V. N.
Carex vulgaris (Fries.) Common. B.
Carex glauca (Scop.) North of the village. B.
Carex pilulifera (Linn.) Frequent. B.
Carex panicea (Linn.) Common. B. V.
Carex binervis (Sm.) Abundant. B.
Carex flava (Linn.) Var. *lepidocarpa* (Tausch.) Sparingly. B.

GRAMINEAE.

Anthoxanthum odoratum (Linn.) Frequent. B. N.
Agrostis canina (Linn.) Rare. B.
Agrostis alba (Linn.) Plentiful. B. S. V.
Agrostis vulgaris (With.) Common. B.
Aira caryophyllea (Linn.) B.
Aira praecox (Linn.) B.
Avena elatior (Linn.) B. V.
Holcus lanatus (Linn.) On the Great Skellig and Tearaght this grass grows very luxuriant. B. S. V.
Triodia decambens (Beauv.) Common. B. V.
Koeleria cristata (Pers.) Shore near the village. B.
Sclerochloa loliacea (Woods.) Sandy strand near the village. B.
Poa annua (Linn.) B.
Poa pratensis (Linn.) B.
†*Poa trivialis* (Linn.) B. V.
Dactylis glomerata (Linn.) B.
Festuca sciuroides (Roth.) B.
Festuca ovina (Linn.) B. V.
Festuca rubra (Linn.) B. V. T.
‡*Bromus mollis* (Linn.) Rare, and possibly introduced. B.
Triticum repens (Linn.) B.
Triticum junceum (Linn.) Near the strand. B.
**Lolium perenne* (Linn.) Relic of cultivation. B.
Nardus stricta (Linn.) Plentiful. B. V.

FILICES.

Hymenophyllum unilaterale (Willd.) On the northern cliffs among loose rocks. B.
Pteris aquilina (Linn.) Common. B. V.
Lomaria spicant (Desv.) B.
Asplenium marinum (Linn.) No specimens from the Blaskets, but I believe it was observed. S.
Asplenium Adiantum nigrum (Linn.) Frequent. B.
Athyrium Filix-foemina (Bernh.) Common. B. V.
Nephrodium dilatatum (Desv.) Frequent. B. N. V.
Nephrodium æmulum (Baker.) Not uncommon. B. N.
Polypodium vulgare (Linn.) Scarce. B. N.

LIST OF PLANTS FOUND ON THE FOLLOWING ISLANDS:—

Tory Island, Co. Donegal.
Aran Island, Co. Donegal.
Innishbofin Island, Co. Mayo.
Arran Islands, Galway Bay.
Blasket Islands, Co. Kerry.

(See page 372, foot-notes.)

LIST OF PLANTS.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Thalictrum minus,	—	—	—	4	—
Ranunculus trichophyllus,	—	—	3	4	—
,, Baudotti,	1	—	3	—	—
,, heterophyllus,	—	—	—	4	—
,, hederaceus,	1	2	3	4	—
,, flammula,	1	2	3	4	5
,, lingua,	—	—	—	4	—
,, acris,	—	2	3	4	—
,, repens,	1	2	3	4	5
,, bulbosus,	—	2	3	4	—
Caltha palustris,	—	2	—	—	—
Aquilegia vulgaris,	—	—	—	4	—
Nuphar lutea,	—	—	3	—	—
Papaver dubium,	—	—	—	4	—
Glaucium luteum,	—	—	—	4	—
Fumaria pallidiflora,	—	—	3	4	—
,, confusa,	—	—	3	—	5
,, officinalis,	—	—	—	4	—
Cakile maritima,	—	2	3	4	5
Crambe maritima,	—	—	—	4	—
Rhaphanus Raphanistrum,	—	—	3	4	—
,, maritimus,	—	—	3	4	—
Sinapis arvensis,	1	—	3	—	5
,, alba,	—	—	3	4	—
,, nigra,	—	—	3	4	—
Brassica Napus,	1	—	3	—	5
Sisymbrium officinale,	—	—	3	4	—
,, Alliaria,	—	—	—	4	—
Hesperis matronalis,	—	—	—	4	—
Matthiola sinuata,	—	—	—	4	—
Cardamine pratensis,	—	—	3	4	5
,, hirsuta,	—	2	—	4	—
,, sylvatica,	—	—	—	—	5
Arabis ciliata,	—	—	—	4	—
,, hirsuta,	—	—	—	4	—
Barbarea vulgaris,	—	—	—	4	—
Nasturtium officinale,	—	2	3	4	—
,, palustre,	—	—	—	4	—
Cochlearia officinalis,	1	—	—	4	5
,, danica,	—	—	3	4	—
Draba verna,	—	2	—	—	—
Thlaspi arvense,	—	—	—	4	—
Capsella bursa-pastoris,	1	—	3	4	5

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Senebiera didyma,	—	—	3	—	—
,, Coronopus,	—	—	3	4	—
Reseda lutea,	—	—	—	4	—
,, Luteola,	—	—	—	4	—
Helianthemum guttatum,	—	—	3	—	—
,, canum,	—	—	—	4	—
Viola palustris,	—	2	3	4	5
,, hirta,	—	—	—	4	—
,, sylvatica,	1	—	3	4	5
,, canina,	—	—	3	—	—
,, tricolor,	—	2	—	4	—
,, Curtisii,	—	—	—	4	—
Drosera rotundifolia,	—	2	3	—	—
Polygala vulgaris,	—	—	—	4	5
,, depressa,	1	2	3	—	5
Silene inflata,	—	—	—	4	—
,, maritima,	1	2	3	4	5
Lychnis Flos-cuculi,	—	—	3	—	5
,, Githago,	—	—	—	—	5
Cerastium tetrandrum,	1	2	3	—	5
,, glomeratum,	—	2	3	4	—
,, triviale,	1	2	3	4	5
,, arvense (Andrewsii),	—	—	—	4	5
Stellaria media,	1	2	3	4	5
,, graminea,	—	—	—	—	5
,, uliginosa,	—	2	—	—	—
Arenaria serpyllifolia,	—	—	3	4	—
Honkeneja peploides,	—	2	3	4	5
Alsine verna,	—	—	—	4	—
Sagina maritima,	1	—	—	4	5
,, apetala,	—	2	—	4	—
,, procumbens,	1	2	3	4	5
,, subulata,	—	—	3	4	—
,, nodosa,	—	—	3	4	—
Spergula arvensis,	1	—	3	—	5
Spergularia neglecta,	1	2	3	4	5
,, rupestris,	1	2	3	4	5
Montia fontana,	1	2	3	—	5
Elatine hexandra,	—	—	3	—	—
Hypericum Androsæmum,	—	—	3	4	—
,, tetrapterum,	—	—	3	4	—
,, humifusum,	—	—	3	4	—
,, pulchrum,	—	2	3	4	5
,, elodes,	—	—	3	—	—
Lavatera arborea,	—	—	—	4	5
Malva sylvestris,	—	—	3	4	—
Radiola millegrana,	1	2	3	—	5
Linum catharticum,	—	2	3	4	—
Geranium sanguineum,	—	—	—	4	—
,, molle,	—	2	3	4	—
,, dissectum,	—	—	3	4	—
,, lucidum,	—	—	—	4	—
,, Robertianum,	—	2	3	4	—

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Erodium cicutarium,	—	2	3	4	—
,, moschatum,	—	—	—	4	—
Oxalis Acetosella,	—	2	3	—	—
Ilex Aquifolium,	—	—	—	4	—
Euonymus europæus,	—	—	—	4	—
Rhamnus catharticus,	—	—	—	4	—
Ulex europæus,	—	2	—	—	—
,, Gallii,	—	—	—	4	—
Anthyllis vulneraria,	—	2	3	4	5
Medicago lupulina,	—	—	—	4	—
Trifolium pratense,	1	2	3	4	5
,, medium,	—	2	—	—	—
,, arvense,	—	—	—	4	—
,, repens,	1	2	3	4	5
,, procumbens,	—	—	—	4	—
,, minus,	—	2	3	4	—
Lotus corniculatus,	1	2	3	4	5
,, major,	—	—	—	4	—
Astragalus hypoglottis,	—	—	—	4	—
Vicia Cracca,	1	2	3	4	5
,, sepium,	—	2	3	4	5
,, sativa,	—	—	3	—	—
,, angustifolia,	—	—	3	—	—
Lathyrus pratensis,	—	—	3	4	5
Prunus spinosa,	—	—	3	4	—
Spiræa Ulmaria,	—	2	3	4	—
Agrimonia Eupatoria,	—	—	3	4	—
Poterium Sanguisorba,	—	—	—	4	—
Alchemilla arvensis,	—	2	—	4	5
,, vulgaris,	—	—	—	4	—
Potentilla Tormentilla,	1	2	3	4	5
,, procumbens,	—	—	3	—	—
,, reptans,	—	2	3	4	—
,, anserina,	1	—	3	4	5
Comarum palustre,	—	—	3	—	—
Fragaria vesca,	—	—	—	4	—
Rubus discolor,	—	2	3	4	5
,, thyrsoideus,	—	—	3	—	—
,, carpinifolius,	—	—	3	—	—
,, villicaulis,	—	—	3	—	—
,, cæsius,	—	—	—	4	—
,, saxatilis,	—	—	—	4	—
Geum urbanum,	—	—	—	4	—
Rosa canina,	—	—	3	4	—
,, spinosissma,	1	2	3	4	—
Cratægus Oxyacantha,	—	—	—	4	—
Lythrum Salicaria,	1	2	3	4	5
Peplis Portula,	1	2	3	—	5
Epilobium hirsutum,	—	—	—	4	—
,, parviflorum,	—	—	3	4	—
,, montanum,	—	2	3	4	—
,, obscurum,	—	—	3	4	5
,, palustre,	—	2	3	—	—

LIST OF PLANTS.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Circæa lutetiana,	—	—	—	4	
Myriophyllum alterniflorum,	1	2	3	4	
Hippurus vulgaris,	—	—	—	4	
Callitriche verna,	1	2	3	4	—
,, platycarpa,	1	2	3	—	5
,, hamulata,	—	—	3	—	—
Sedum Rhodiola,	—	2	—	4	—
,, anglicum,	1	2	3	4	5
,, acre,	—	2	3	4	—
Cotyledon Umbilicus,	—	—	—	4	5
Saxifraga umbrosa,	—	—	3	—	5
,, tridactylites,	—	—	—	4	—
,, hirta,	—	2	—	—	—
,, hypnoides,	—	—	—	4	—
Hydrocotyle vulgaris,	1	2	3	4	5
Sanicula europæa,	—	—	—	4	—
Eryngium maritimum,	—	—	—	4	—
Apium graveolens,	—	—	—	4	—
Helosciadium nodiflorum,	1	2	—	4	—
,, inundatum,	—	—	3	4	—
Pimpinella magna,	—	—	—	4	—
Ægopodium Podagraria,	—	2	—	—	—
Æthusa Cynapium,	—	—	—	4	—
Ligusticum scoticum,	1	—	—	4	—
Crithmum maritimum,	1	—	3	4	5
Angelica sylvestris,	1	2	3	4	5
Patsinaca sativa,	—	—	—	4	—
Heracleum Sphondylium,	1	2	3	4	5
Daucus Carota,	1	2	3	4	5
Torilis Anthriscus,	—	—	—	4	—
,, nodosa,	—	—	—	4	—
Chærophyllum Anthriscus,	—	—	—	4	—
,, sylvestre,	—	—	—	4	—
Conium maculatum,	—	—	3	4	—
Smyrnium olusatrum,	—	—	—	4	—
Hedera Helix,	1	2	3	4	5
Cornus sanguinea,	—	—	—	4	—
Sambucus nigra,	—	—	3	4	
,, Ebulus,	—	—	—	4	—
Viburnum Opulus,	—	—	—	4	—
Lonicera Periclymenum,	1	2	3	4	—
Rubia peregrina,	—	—	—	4	—
Galium boreale,	—	—	—	4	—
,, verum,	—	2	3	4	5
,, saxatile,	—	2	3	—	5
,, sylvestre,	—	—	—	4	—
,, palustre,	—	—	3	4	—
,, Witheringii,	1	—	3	—	—
,, Aparine,	—	—	3	4	5
Asperula cynanchica,	—	—	—	4	—
Sherardia arvensis,	—	—	—	4	—
Valeriana officinalis,	—	—	—	4	5
Valerianella olitoria,	—	—	—	4	—

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Scabiosa succisa,	1	2	3	4	—
Silybum Marianum,	—	—	—	4	—
Carduus tenuiflorus,	—	—	—	4	—
,, nutans,	—	—	—	4	—
,, lanceolatus,	1	2	3	4	5
,, palustris,	—	2	3	—	—
,, pratensis,	1	2	—	—	—
,, arvensis,	1	2	3	4	5
Carlina vulgaris,	—	—	—	4	—
Arctium minus,	—	2	—	—	—
,, intermedium,	1	—	3	4	5
Centaurea nigra,	1	2	3	4	5
,, Scabiosa,	—	—	3	4	—
Chrysanthemum segetum,	1	2	3	4	—
,, Leucanthemum,	—	2	3	4	—
Matricaria inodora,	1	2	3	4	5
Tanacetum vulgare,	—	—	—	4	—
Achillea Millefolium,	—	2	3	4	5
,, Ptarmica,	—	2	3	4	—
Artemisia Absinthium,	—	—	—	4	—
,, vulgaris,	1	2	3	4	5
Filago germanica,	—	—	—	4	—
Gnaphalium uliginosum,	1	2	3	4	5
,, dioicum,	—	2	—	4	—
Senecio vulgaris,	1	2	3	4	5
,, sylvaticus,	1	2	3	—	—
,, Jacobæa,	1	2	3	4	5
,, aquaticus,	1	2	3	4	—
Inula dysenterica,	—	—	3	4	—
Bellis perennis,	1	2	3	4	5
Aster Tripolium,	—	—	3	4	—
Solidago Virga-aurea,	1	2	3	4	5
Tussilago Farfara,	—	2	3	4	5
Eupatorium cannabinum,	—	—	—	4	—
Lapsana communis,	—	2	3	4	5
Hypochæris radicata,	1	2	3	4	5
Leontodon hirtus,	—	—	3	—	—
,, autumnalis,	1	2	3	4	5
Taraxacum officinale,	1	2	3	4	5
Sonchus oleraceus,	1	2	3	4	5
,, asper,	1	2	3	4	5
,, arvensis,	—	2	3	3	5
Crepis virens,	—	2	—	4	—
Hieracium Pilosella,	—	2	3	4	—
,, anglicum,	—	—	—	4	—
Lobelia Dortmanna,	—	2	3	—	—
Jasione montana,	1	2	3	—	5
Campanula rotundifolia,	—	2	3	4	—
Vaccinium Myrtillus,	—	2	—	—	5
Arctostaphylos Uva-ursi,	—	2	—	—	—
Erica Tetralix,	—	2	3	—	5
,, cinerea,	1	2	3	4	5
Calluna vulgaris,	1	2	3	4	5

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Fraxinus excelsior,	—	—	—	4	—
Erythræa Centaurium,	1	2	3	4	5
Chlora perfoliata,	—	—	—	4	—
Gentiana verna,	—	—	—	4	—
,, campestris,	—	2	3	4	—
Menyanthes trifoliata,	—	2	3	4	—
Convolvulus arvensis,	—	—	—	4	—
,, sepium,	—	2	3	4	—
,, Soldanella,	—	—	—	4	—
Solanum dulcamara,	—	—	—	4	—
Verbascum thapsus,	—	—	—	4	—
Scrophularia aquatica,	—	—	3	—	—
,, nodosa,	—	—	—	4	—
Digitalis purpurea,	—	2	—	—	—
Linaria vulgaris,	1	—	—	—	—
Veronica hederifolia,	—	2	—	4	—
,, polita,	—	—	3	—	5
,, agrestis,	—	—	3	4	—
,, arvensis,	—	—	3	4	5
,, serpyllifolia,	—	2	—	4	5
,, officinalis,	—	2	—	4	—
,, Chamædrys,	—	2	3	4	—
,, Anagallis,	—	—	3	4	—
,, Beccabunga,	—	—	3	4	—
Euphrasia officinalis,	1	2	3	4	5
Bartsia odontites,	1	2	3	4	5
Pedicularis palustris,	—	—	3	4	—
,, sylvatica,	—	2	3	4	5
Rhinanthus Crista-galli,	1	2	3	4	—
Orobanche Hederæ,	—	—	—	4	—
Lycopus europæus,	—	—	—	4	—
Mentha aquatica,	—	—	3	4	—
,, arvensis,	—	—	—	4	—
Thymus serpyllum,	1	2	3	4	5
Calamintha officinalis,	—	—	—	4	—
Nepeta Glechoma,	—	—	—	4	—
Prunella vulgaris,	1	2	3	4	5
Scutellaria minor,	—	—	3	—	—
Marrubium vulgare,	—	—	—	4	—
Stachys palustris,	1	2	3	4	5
,, sylvatica,	—	—	—	4	—
,, arvensis,	1	—	3	4	—
Galeopsis Tetrahit,	—	2	3	4	5
Lamium amplexicaule,	1	—	—	—	5
,, intermedium,	1	2	—	—	—
,, incisum,	1	2	—	—	5
,, purpureum,	1	2	3	4	5
Ajuga reptans,	—	—	—	4	—
,, pyramidalis,	—	—	—	4	—
Teucrium Scorodonia,	—	—	3	4	5
Lithospermum officinale,	—	—	—	4	—
Myosotis cæspitosa,	1	2	3	—	—
,, palustris,	—	—	—	4	—

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Myosotis repens,	—	2	—	—	—
,, arvensis,	1	2	3	4	5
,, versicolor,	—	—	—	4	—
Symphytum officinale,	—	—	—	4	—
Pinguicula vulgaris,	—	—	3	—	—
,, lusitanica,	—	—	3	—	—
Utricularia minor,	—	—	3	—	—
Primula vulgaris,	—	2	3	4	5
Lysimachia nemorum,	—	—	—	4	—
Anagallis arvensis,	—	2	3	4	5
,, tenella,	1	2	3	4	5
Centunculus minimus,	—	—	3	—	—
Glaux maritima,	1	2	3	4	—
Samolus valerandi,	—	—	3	4	—
Armeria maritima,	1	2	3	4	5
Statice occidentalis,	—	—	—	4	—
Plantago major,	1	2	3	4	5
,, lanceolata,	1	2	3	4	5
,, maritima,	1	2	3	4	5
,, coronopus,	1	2	3	4	5
Littorella lacustris,	1	2	3	4	—
Suæda maritima,	—	—	—	4	5
Salsola Kali,	—	2	3	4	—
Salicornia herbacea,	—	—	—	4	—
Beta maritima,	1	2	—	4	5
Chenopodium album,	1	2	3	4	5
Atriplex littoralis,	—	—	—	4	—
,, angustifolia,	1	2	3	4	5
,, erecta,	—	2	3	—	—
,, deltoidea,	—	2	—	—	—
,, Babingtonii,	1	2	3	—	5
Rumex conglomeratus,	—	—	—	4	—
,, obtusifolius,	1	2	3	4	5
,, crispus,	1	—	3	—	5
,, Acetosa,	1	2	3	4	5
,, Acetosella,	1	2	3	4	5
Polygonum convolvulus,	—	—	3	4	—
,, aviculare,	1	2	3	4	5
,, Raii,	—	—	—	4	—
,, Hydropiper,	—	2	3	4	—
,, Persicaria,	—	2	3	4	5
,, amphibium,	1	—	3	4	—
Empetrum nigrum,	1	2	3	—	5
Euphorbia Helioscopia,	—	2	3	4	5
,, Paralias,	—	—	—	4	—
,, portlandica,	—	—	—	4	—
,, Peplus,	—	—	—	4	—
Parietaria officinalis,	—	—	—	4	—
Urtica dioica,	1	2	3	4	5
,, urens,	1	2	3	4	—
Humulus Lupulus,	—	—	—	4	—
Quercus robur,	—	2	—	4	—
Corylus avellana,	—	2	—	4	—

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Alnus glutinosa,	—	2	—	—	—
Betula alba,	—	2	—	—	—
Myrica Gale,	—	2	3	—	—
Populus alba,	—	—	—	4	—
,, tremula,	—	2	3	—	—
Salix viminalis,	—	—	3	4	—
,, Smithiana,	—	—	3	—	—
,, cinerea,	—	2	—	—	—
,, aurita,	—	—	3	—	—
,, caprea,	—	—	—	4	—
,, repens,	1	2	3	4	—
Juniperus communis,	—	—	—	4	—
,, nana,	—	2	3	—	—
Sparganium affine,	1	—	3	—	—
,, minimum,	—	2	—	—	—
Arum maculatum,	—	—	—	4	—
Lemna minor,	—	2	3	4	—
Potamogeton natans,	—	—	3	4	—
,, polygonifolius,	1	2	3	—	—
,, pusillus,	—	—	3	—	—
,, pectinatus,	—	—	3	4	—
Zostera marina,	—	2	3	4	—
Triglochin palustre,	1	—	3	4	—
,, maritimum,	—	—	—	4	—
Alisma ranunculoides,	—	—	—	4	—
Orchis pyramidalis,	—	—	—	4	—
,, mascula,	—	—	—	4	—
,, maculata,	1	2	3	—	5
Gymnadenia conopsea,	—	—	—	4	—
Habenaria viridis,	—	—	—	4	—
Spiranthes autumnalis,	—	—	—	4	—
Iris Pseud-acorus,	1	2	3	4	—
Narcissus biflorus,	—	—	—	4	—
Allium Babingtonii,	—	—	3	4	—
Scilla nutans,	—	—	—	—	5
Narthecium ossifragum,	—	2	3	—	—
Eriocaulon septangulare,	—	—	3	—	—
Luzula sylvatica,	—	—	—	—	5
,, campestris,	—	—	—	4	—
,, multiflora,	1	2	3	—	5
Juncus maritimus,	—	2	—	—	—
,, conglomeratus,	1	—	3	—	5
,, effusus,	—	2	3	4	—
,, acutiflorus,	1	—	3	4	—
,, lamprocarpus,	—	—	3	—	5
,, supinus,	1	—	3	—	5
,, bufonius,	1	2	3	4	5
,, Gerardi,	1	—	3	—	—
,, compressus,	—	2	—	—	—
,, squarrosus,	—	2	3	—	5
Schœnus nigricans,	1	—	3	4	—
Rhynchospora alba,	—	—	3	—	—
Scirpus palustris,	1	2	3	—	—

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Scirpus multicaulis,	1	2	3	—	—
,, fluitans,	—	—	3	—	—
,, Savii,	1	2	3	4	5
,, setaceus,	—	—	—	4	5
,, lacustris,	—	—	—	4	—
,, maritimus,	—	2	—	4	—
Eriophorum angustifolium,	—	—	3	—	5
Carex pulicaris,	—	—	3	—	—
,, disticha,	—	—	—	—	5
,, arenaria,	—	2	3	4	—
,, vulpina,	—	—	—	4	—
,, stellulata,	—	2	3	—	5
,, vulgaris,	1	2	—	—	5
,, glauca,	1	2	3	4	5
,, pilulifera,	—	—	—	—	5
,, præcox,	—	2	3	—	—
,, panicea,	—	—	3	—	5
,, binervis,	—	2	3	—	5
,, distans,	—	2	3	4	—
,, extensa,	1	2	3	—	—
,, flava,	—	—	—	4	—
,, lepidocarpa,	—	—	3	—	5
,, œderi,	1	—	—	4	—
,, ampullacea,	—	—	3	—	—
Anthoxanthum odoratum,	1	2	3	4	5
Digraphis arundinacea,	—	—	—	4	—
Alopecurus geniculatus,	1	—	—	4	—
,, pratensis,	—	2	—	—	—
Phleum pratense,	—	—	—	4	—
,, arenarium,	—	—	—	4	—
Sesleria cærulea,	—	—	—	4	—
Agrostis canina,	1	2	3	4	5
,, alba,	1	2	3	4	5
,, vulgaris,	—	2	3	4	5
Psamma arenaria,	—	—	3	—	—
Calamagrostis Epigejos,	—	—	3	4	—
Phragmites communis,	1	2	3	4	—
Aira cæspitosa,	—	2	—	4	—
,, flexuosa,	—	2	3	—	—
,, caryophyllea,	—	2	3	4	5
,, præcox,	1	2	3	4	5
Avena fatua,	—	—	3	—	—
,, elatior,	—	2	3	4	5
Holcus lanatus,	1	2	3	4	5
Triodia decumbens,	1	2	3	—	5
Kœleria cristata,	—	—	3	—	5
Molinia cærulea,	—	2	3	4	—
Catabrosa aquatica,	—	2	—	—	—
Glyceria fluitans,	1	2	3	4	—
,, plicata,	—	—	3	—	—
Sclerochloa maritima,	—	2	—	4	—
,, rigida,	—	—	—	4	—
,, loliacea,	1	—	3	4	5

List of Plants.	Tory.	North Aran.	Bofin.	South Arran.	Blaskets.
Poa annua,	—	2	3	4	5
,, pratensis,	1	—	3	4	5
,, trivialis,	1	—	3	—	5
Cynosurus cristatus,	—	2	3	4	—
Dactylis glomerata,	—	2	3	4	5
Festuca sciuroides,	—	—	3	—	5
,, ovina,	—	2	3	4	5
,, rubra,	1	—	3	4	5
,, elatior,	—	—	3	—	—
,, pratensis,	—	—	3	4	—
Bromus sterilis.	—	2	—	—	—
,, mollis,	1	2	3	4	5
Brachypodium sylvaticum,	—	—	3	4	—
Triticum repens,	1	2	3	4	5
,, junceum,	—	2	3	4	5
Lolium perenne,	1	—	3	4	5
,, temulentum,	—	—	3	—	—
Elymus arenarius,	—	2	—	—	—
Nardus stricta,	1	2	3	—	5
Hymenophyllum unilaterale,	—	—	—	—	5
Adiantum Capillus-Veneris,	—	—	—	4	—
Pteris aquilina,	1	2	3	4	5
Lomaria spicant,	1	2	3	4	5
Asplenium Ruta-muraria,	—	—	3	4	—
,, Trichomanes,	—	—	—	4	—
,, marinum,	1	2	3	4	5
,, adiantum nigrum,	—	2	3	4	5
Athyrium Filix-fœmina,	1	2	3	—	5
Ceterach officinarum,	—	—	—	4	—
Scolopendrium vulgare,	—	—	—	4	—
Aspidium angulare,	—	—	—	4	—
Nephrodium Filix-mas,	—	2	3	—	—
,, dilatatum,	1	2	3	4	5
,, æmulum,	—	2	3	—	5
Polypodium vulgare,	—	2	3	4	5
Osmunda regalis,	—	2	3	—	—
Isoetes lacustris,	—	2	—	—	—
,, echinospora,	—	—	3	—	—
Equisetum arvense,	—	2	3	—	—
,, hyemale,	—	—	—	4	—
,, limosum,	—	—	3	—	—

LXI.—On the Botany of the Galtee Mountains, Co. Tipperary. By Henry Chichester Hart.

[Read, February 14, 1881.]

Having received a grant from the Royal Irish Academy, in 1880, to enable me to examine the Botany of the Galtee Mountains I beg to lay the following results before the Academy:—

Upon the 3rd of August I reached Tipperary, and the following day commenced the detailed exploration of the mountains. My visit, owing to rough weather, was later than I had intended; but the flowering season was not very far advanced when I arrived, and having spent six days upon the range, I do not think it likely that many plants of interest escaped my notice.

The Galtee range extends for about fifteen miles, from Caher at the eastern to Massy Lodge at the western extremity. These mountains form a long ridge, intersected by no transverse valley, and sloping with tolerable evenness to the plains on the south, while they descend with abrupt declivities and a series of cliff-girt tarns to the Vale of Aherlow upon the north. This ridge, which maintains an elevation of above 2500 feet for eight or nine miles, and reaches its greatest height (3015 feet) at Galtymore, about the centre of the range, forms an accurate boundary for the alpine vegetation of the range. Upon the slopes descending southward, though starting from the summit, I met with no alpine or northern type plants; all these, which form its chief botanical interest, lie on the northern face of the mountains.

The geological structure of this backbone of the Co. Tipperary is of Silurian age, with overlying beds of Old Red Sandstone conglomerate, reaching to the summit at Galtymore. The Silurian beds are chiefly a series of clayey and micaceous shales and slate, which form considerable precipices upon the northern side, overhanging and nearly surrounding several mountain lakes. To these favoured spots the alpine vegetation of the mountain is almost entirely confined.

As we go from east to west, we meet with four of these lakes, namely—Lough Curra (1850 feet); Lough Diheen, "Tanyagh" of the natives (1800 feet); Lough Borheen (1700 feet); and Muskry Lough (1500 feet), the numbers after each representing their estimated height above sea-level. Of these, Lough Curra is the most interesting to botanists, as well as being the easiest of access; the cliffs descend from about 1000 feet above, sheer into the water, and around its shores several alpine plants grow luxuriantly. Lough Diheen is the most remote, and the scenery around it is very imposing: this lake and its shores are quite devoid of vegetation—on one side lies a terminal moraine, the relic of an ancient glacier; the water is of

an intensely-dark hue; and the sombre colouring of the lofty cliffs above give quite an arctic character to the scene.

In order to point out to a botanical friend the chief points of interest upon the Galtee Mountains, I would ask him to accompany me upon a long and arduous walk, from Massy Lodge at the western extremity of the range to Caher at the east, and to visit on our way each of the lakes and the cliffs, slopes, and river beds upon either side.

At about 700 or 800 feet above sea-level cultivation has ceased to affect the flora, and we no longer meet with any species introduced by the agency of man. If we ascend Thumpadour, 2570 feet on Ordnance Map, my botanical friend will be no doubt much disappointed at not gathering a single plant of interest. To the east of this summit lies a considerable depression, so that this first point is an isolated outlier of the range. Encouraged by this reflection we cross this valley, and ascend Corrig-na-binnian, 2712 feet. On the way up, *Saxifraga stellaris* is met with; and on the northern bluffs, below the summit, *S. hirta* (vars. *affinis* and *platypetala*), a characteristic plant of these mountains, may be seen. On the northern side of this summit there is a considerable valley, Glan-cush-na-binnian, in which, at about 1500 feet below the summit, *Meconopsis cambrica* may be gathered; it grows here in several places by the stream above Stone Park. Here, too, we find *Scolopendrium vulgare*, a couple of plants by a waterfall, the only place it appears to occur on the mountains; *Carex ovalis* also grows in this valley, elsewhere met with only at Lough Muskry, and below Lough Curra. Advancing eastward from the last summit to the heights above Lough Curra, and descending about 200 feet on the north of the ridge, we may gather *Hymenophyllum tunbrigense;* and on cliffs a little below the point marked 2544 feet on the Ordnance Map, about half a mile west of Lough Curra, we first meet with *Asplenium viride* and *Cystopteris fragilis*. These two ferns become abundant and luxuriant around and above Lough Curra. In one place here, too, grows the rare *Arabis petræa*, whose only previously-known habitat in Ireland is Glenade Mountain, in Co. Leitrim. It grows here in small quantities upon one bluff, facing east of north, at an altitude of about 2600 feet, above and to the west of Lough Curra. There were neither flowers nor pods upon this scarce little crucifer, but a comparison with living specimens in the College Botanic Gardens enabled me to identify the plant. This was the most interesting plant observed upon the Galtees.

Besides the species already named, several other alpine plants abound around Lough Curra, especially at and for about 100 feet above the lake—as *Oxyria reniformis*, *Sedum Rhodiola*, *Saxifraga stellaris*, *Cochlearia officinalis* (var. *alpina*), and in smaller quantities *Hieracium anglicum*. The lake itself contained no aquatic plants, except *Litorella lacustris*—not even *Callitriche hamulata*. These cliffs are more alpine in character than those around the other lakes, contain-

ing, as they do, the greatest number of alpine and the smallest of lowland plants. Lough Curra is easy of access, and will well repay a visit.

From here we will make a descent by the stream from the lake to the borders of cultivation at about 750 feet, noting the heights at which the more lowland species begin to appear, and reversing the process upon our return, so as to obtain the lower limits of the alpine species. Upon this detour, we meet with *Pinguicula lusitanica* and *Drosera rotundifolia* sparingly, in one place at an altitude of 850 to 900 feet; these were not met with elsewhere upon the Galtee range, and the rarity of plants so frequent on Irish mountain ranges seems unaccountable. The results of these observations will be found in the appended list; but it may be mentioned here, that none of the alpine plants, except *Saxifraga stellaris*, descend below the levels of the cliff-bases, corresponding with the altitudes of the lakes given above.

Having examined the attractive, though dangerous, precipices of Lough Curra, and the high ground above, as well as the northern slopes below, we will take a botanical survey of the southern descent towards Mitchelstown. Once the ridge is crossed and we face downwards, we meet with a gradually-diminishing mountain flora of the commonest type, which, as far as my observations went, contained no remarkable plant. Four distinct excursions upon this southern aspect of the Galtees led me to this conclusion; we will, therefore, resume our course at Lough Curra, and pursue it in an easterly direction.

Having crossed a spur running north from Dawson's Table (Galtymore), we came upon Lough Diheen (1800 feet)—a small and perfectly barren tarn sunk in a cradle of glacial drift. This lake is about three parts surrounded by precipices, which do not quite reach the water, and is fringed with piled moraine matter in a barrier about 20 to 30 feet high. To the student of ice-action this lake will be of interest, but to explore the botany we must scramble up amongst the precipices. Keeping upward towards Galtymore, and examining the different ledges on the faces of the cliffs, we notice merely a diminution in the flora, and find nothing of much interest until within about 400 feet of Galtymore. Here is a small patch of the rare *Saussurea alpina*, consisting of but four or five plants. This plant has been hitherto known only from two places in the Kerry mountains, and was recently rediscovered by me in the Co. Donegal. We will leave these few roots undisturbed. Many lowland plants abound here at an unusual height. *Chrysosplenium oppositifolium* and *Montia fontana* are very plentiful within 200 feet of the summit, and *Rhinanthus Crista-galli* occurs at an altitude of about 2400 feet. As we still travel east from Lough Diheen, and examine the bases of the wet bluffs and north-looking cliffs, we again notice *Asplenium viride* and *Oxyria reniformis*, though decreasing in quantity. *Saxifraga hirta*, vars. *genuina*, *platypetala* and *affinis*, also occur, the last two being the most abundant. At an altitude of about 2600 feet north of Lough Diheen, *Salix herbacea* also appears; it occurred previously

in one place about 20 feet below the summit of Galtymore, and ranges eastward from that to the Muskry cliff. This alpine plant chooses the cracks and fissures in bare and wind-blown summits, despising the moisture and shelter which the others seem to require. After a few more hours' climbing we come in view of Lough Borheen (1700 feet). The vegetation around this lake is less alpine in character than that of the others, and around its shores many fresh lowland species occur, as *Bellis perennis*, *Trifolium pratense*, *T. arvense*, Leontodon, Taraxacum, &c. At the northern corner, and down to the level of the lake, *Asplenium viride* and *Saxifraga hirta*, var. *platypetala;* and here, for the first time, we gather the London Pride Saxifrage (*Saxifraga umbrosa*), which is a truly alpine plant upon the Galtee range, although it does not extend westward to Galtymore. Eastward of Lough Borheen it becomes abundant; near this lake, too, about a quarter of a mile east, we find *Vaccinium Vitis-idæa* for the first time. It appears again at Lough Muskry.

Having explored this coomb and its surroundings, we will pursue our line of march, keeping along the high ground which breaks at length into the magnificent range of cliffs above Lough Muskry. I spent a long day climbing amongst their numerous clefts and ledges, the cliffs themselves towering to a height of about 1200 feet in vast verdant walls and terraces to the north and north-east of the lake. With the exception of Arabis and Saussurea, the alpine plants reappear here in great profusion. Two rarities seem peculiar to these cliffs, *Thalictrum minus* and *Geum rivale*, occurring up to 2000 feet. The most-finely cut leaved form of *Saxifraga hirta* (i. e. var. *genuina*) is very abundant here, forming in some places the entire green sward at the base of the cliffs. Several plants also reach an unexpected altitude above Lough Muskry. *Carex paniculata* grows at the level of the lake (1500 feet), and above it to a height of 1900 feet. Other lowland plants not before gathered occur around its shores, amongst which a remarkably starved form of *Polygonum hydropiper* may be mentioned.

We will make a descent from here into the Vale of Aherlow, and repeat the same observations upon the upper and lower limits of the two groups of plants, lowland or mountain. On this part of the Galtees we gather *Sarothamnus scoparius* and *Lastrea æmula*, on the borders of an extensive plantation, at about 800 feet altitude. The fern is scarce on the Galtees, but it occurs also on the southern side at about 1200 feet. A few other plants of no special interest are added to the list; and bearing upwards and to the east again, we will follow the range, down to Caher. Along the crest of the cliffs above Lough Muskry, at about 2600 feet, *Empetrum nigrum*, *Lycopodium selago*, *Saxifraga stellaris*, and *S. umbrosa* occur: soon these latter three disappear, and the usual mountain plants are alone to be met with. The eastern extremity of the range is very barren; some points and a considerable extent on their flanks being entirely free from vegetation—a desolate waste of sandstone and conglomerate *débris*.

At Slieve Anard (1457 feet), *Pteris aquilina* occurs, about 100 feet below the summit—a remarkable altitude for this fern; and at 1250 feet *Ulex Gallii* and *U. europæus* appear together—an unusual height at which to meet either kind of furze. Nothing worthy of mention will be met with at this extremity of the range, which descends gradually into the plain of Tipperary.

The foregoing is a sketch of the ground gone over and observations taken during six consecutive days, which I divided as follows:—*First day* (August 4)—From Tipperary to Lough Curra, examined shores and cliffs about lake; reached summit of Galtymore, and walked down to Mitchelstown. This day it never ceased pouring rain. *Second day*—From Mitchelstown by the mountain lodge to the ridge above Lough Borheen, making many detours on the southern slopes; examined shores and cliffs of this lake, and travelled westward along cliffs above Lough Diheen to a further examination of Lough Curra; walked into Tipperary. *Third day*—Up by Knockmoyle and other summits to Lough Diheen; climbed cliffs and ravines to the north of the lake, and along ridges, and all the range down to Massy Lodge at its western end, home to Tipperary. *Fourth day*—Up to Lough Curra again, to examine some ravines not previously searched, and then explored eastwards along the range to Caher. This was a dreadful day on the mountains; storm and rain from start to finish. *Fifth day*—Up the northern side from near Castlemary (about half way between Tipperary and Caher), through an extensive plantation to Lough Muskry; spent the day amongst the precipices there, and had much severe climbing; walked into Tipperary. This was a long and successful day's work. *Sixth day*—Up by Stone Park, through Glan-cush-na-binnian, and along ridge to Loughs Curra and Diheen, and home to Tipperary; a very wet afternoon, and there seemed nothing left that required exploration; so that I concluded my labours with this walk. Thus I hope that I explored the range completely, with the exception of the lowland portions, especially on the southern side. An accident, which I much regretted, was the breaking of my aneroid, and I was deprived of its use until two days before leaving. However, on the last day, I verified many points which I had before estimated from the heights given on the Ordnance Map, and I took many observations of points by which to check my previous notes. I cannot refrain from mentioning here what a misfortune it is that the southern counties are not marked with the contoured lines of elevation on the Ordnance Maps, as the northern are. It seems very strange that at present there is no means, from any map, of finding the altitudes of such well-defined bases for observation as mountain lakes, or indeed of any points except the marked summits. There are four mountain lakes (some of considerable size) on the Galtee range, and yet there is no record in the Ordnance or Geological Survey Offices of the heights of any one of these lakes above sea level. This was a condition of affairs I had not foreseen; and had I known I was to be entirely dependent upon my aneroid, I should

have taken care to have provided myself with a spare one. Even so, however, some authenticated observations by the officers of the Survey would be desirable as a check.

In summarizing the results of my observations, I wish first to mention that my friend A. G. More agrees with me that a slight alteration in the relative boundaries of Districts 6 and 2 of the Cybele Hibernica would be advantageous. As the map there stands, the Galtee range enters into both these districts; and I would suggest that the part of District 6 which includes a small western portion of the Galtee range be joined to District 2. The road running south, from Galbally to Ballyarthur, would form a good natural division, and in this way the whole Galtee range is included in District 2. A glance at the map will show that this is a natural division.

The following is a list of the alpine plants, ten in number, found upon the Galtees—all of these belong to Watson's Highland type:—

Arabis petræa.	*Vaccinium Vitis-idæa.*
Sedum Rhodiola.	*Oxyria reniformis.*
Saxifraga stellaris.	*Salix herbacea.*
Hieracium anglicum.	*Asplenium viride.*
Saussurea alpina.	*Cochlearia officinalis* (var. *alpina*).

This alpine flora is below the average for Irish mountain ranges, and this is the more remarkable when the elevation of the Galtymore chain is considered. In fact, with the exception of the Wicklow mountains, the highest point of which is a few feet higher than Galtymore, the Galtees yield the poorest flora of any range in Ireland. On the other hand, they can carry up many lowland species to an unusual altitude. Another feature in the flora of this range is worthy of notice—the extreme rarity, or entire absence, of many common Irish mountain plants. It is, of course, unsafe to say that any species not observed is really absent, but I can safely say that the following are very rare or wanting:—*Drosera rotundifolia, Pinguicula lusitanica,* mountain Hieracia of all kinds, *Myrica Gale, Isoetes lacustris, Antennaria dioica, Juniperus communis.* Of these, the last four were not met with at all.

Of Watson's Scottish or Northern type only three species occur: *Thalictrum minus, Saxifraga hirta, Crepis paludosa,* a very small proportion of the Irish species (66). But this might have been expected, from the southern position of the locality.

The following are additions to District 2 of the Cybele Hibernica:—

Thalictrum minus.	*Pyrus aucuparia.*
Arabis petræa.	*Saussurea alpina.*
Polygala depressa.	*Myosotis repens.*

The occurrence of *Meconopsis cambrica* and *Hieracium anglicum* upon this range, as giving new localities for two rare Irish plants, although each had one previous station in the district, is important.

As the districts stand at present, *Carex ovalis* is an addition to District 6, but I prefer to include it in District 2.

There are three tolerably distinct forms of *Saxifraga hypnoides* to be met with on the Galtee range. Following the names given in Syme's English Botany, these seem to be *S. hirta*, var. *genuina* and var. *affinis* and *S. eu-hypnoides*, var. *platypetala*. All may be met with in various parts of this range, and to a considerable extent, irrespectively of altitude; but *S. affinis* is the form usually to be found at the greatest heights: *S. platypetala* in the wetter and mossy places by streams at lower levels; while *S. hirta*, var. *genuina*, the finest-cut form with bristle-pointed leaves, is especially characteristic of the bases of the loftier cliffs, as at Lough Muskry. *S. hirta* of the Galtees is much less hairy than the Donegal plant found by me on Aranmore;[1] but in other respects they are, I believe, identical.

My experience of these Irish Saxifrages and of the innumerable arctic forms of *S. cæspitosa* leads me to believe that an unbroken chain from the extreme forms of *S. hypnoides* to those of *S. cæspitosa* might be enumerated which would defy division. But it is unfortunately necessary to have names for forms belonging to different countries.

In conclusion, I have to acknowledge my obligations to Mr. Backhouse, who kindly examined some Saxifrages and Hieracia; and to my friend Mr. A. G. More, who has, as usual, afforded me every assistance in his power.

General list of the Plants observed on the Galtee mountains, arranged in descending order. This arrangement has been adopted for the convenience of comparison with other mountain ranges. Special localities or other remarks will be found given in the introductory remarks. The alpine and most characteristic plants are printed in italics.

Summit of Galtymore.

3015 feet.

Galium saxatile, Linn.
Calluna vulgaris, Salisb.
Rumex Acetosella, Linn.
Agrostis vulgaris, With.
Aira flexuosa, Linn.
Festuca ovina, Linn.

3000 feet.

Stellaria uliginosa, Murr.
Saxifraga stellaris, Linn. (to 1200 feet).
Chrysosplenium oppositifolium, L.
Vaccinium Myrtillus, Linn.
Rumex Acetosa, Linn.
Salix herbacea, Linn. (to 2200 feet).
Luzula sylvatica, Beck.
Eriophorum vaginatum, Linn.
Poa annua, Linn.

[1] See *Journal of Botany*, January, 1881.

2850 feet.

Montia fontana, Linn.
Potentilla Tormentilla, Schenk.
Cystopteris fragilis, Bernh. (to 1850 feet).
Asplenium viride, Huds. (to 1500 feet).
Lastrea Filix-mas, Presl.

2650 feet.

Arabis petræa, Lam. (in one place only).

2600 feet.

Solidago Virga-aurea, Linn.
Saussurea alpina, D. C. (only station).
Empetrum nigrum, Linn.
Oxyria reniformis, Hook. (to 1500 feet).
Carex stellulata, Good.
Lycopodium Selago, Linn.

2570 feet.

Saxifraga hirta et vars. (to 700 feet).

2500 feet.

Ranuculus Flammula, Linn.
Cardamine pratensis, Linn.
Cerastium triviale, Link.
Epilobium palustre, Linn.
Sedum Rhodiola, D. C. (to 1850 feet).
Saxifraga umbrosa, Linn. (to 1750 feet.
Angelica sylvestris, Linn.
Leontodon autumnalis, Linn.
Crepis paludosa, Moench.
Jasione montana, Linn.
Campanula rotundifolia, Linn.
Juncus squarrosus, Linn.
Carex vulgaris, Fries.
Lomaria spicant, Deov.
Hymenophyllum Tunbrigense Sm.
Lastrea dilatata, Presl.

2400 feet.

Chærophyllum sylvestre, Linn.
Valeriana officinalis, Linn.
Rhinanthus Crista-galli.
Melampyrum pratense, Linn. (Var. montanum).
Euphrasia officinalis, Linn.
Carex flava, Linn.
Polypodium vulgare, Linn.

2200 feet.

Vaccinium Vitis-Idæa, Linn. (to 2000 feet).
Carex ovalis, Good.
C. binervis, Sm.
Poa pratensis, Linn.
Asplenium Trichomanes, Linn.

2150 feet.

Erica cinerea, Linn.

2100 feet.

Stellaria media, With.
Digitalis purpurea, Linn.
Anthoxanthum odoratum, Linn.

2000 feet.

Thalictrum minus, Linn. (only station).
Cochlearia officinalis, Linn. (to 1850 feet).
Viola palustris, Linn.
Hypericum pulchrum, Linn.
Oxalis Acetosella, Linn.
Geum rivale, Linn. (only station).
Pyrus aucuparia, Gært.
Hieracium anglicum (to 1900 feet).
Pedicularis sylvatica, Linn.
Luzula campestris, D. C.

1950 feet.

Veronica officinalis, Linn.
Pteris aquilina, Linn.

1900 feet.

Epilobium montanum, Linn.
Scabiosa succisa, Linn.
Primula vulgaris, Huds.
Carex paniculata, Linn.

1850 feet (Lough Curra level).

Stellaria Hnolostea, Linn.
Alchemilla vulgaris, Linn.
Litorella lacustris, Linn.
Juncus supinus, Moench.
Agrostis vulgaris, var. pumila, With.

1800 feet.

Ranunculus Ficaria, Linn.

1750 feet.

Cardamine hirsuta, Linn.

1700 feet (Borheen Lake level).

Ranunculus repens, Linn.
R. acris, Linn.
Lychnis diurna, Sibth.
Trifolium repens, Linn.
Rubus Idæus, Linn.
Callitriche platycarpa, Scop.
Bellis perennis, Linn.
Veronica serpyllifolia, Linn.
Ajuga reptans, Linn.
Prunella vulgaris, Linn.
Lysimachia nemorum, Linn.
Potamogeton natans, Linn.
Carex glauca, Scop.

1600 feet.

Geranium Robertianum, Linn.
Orobus tuberosus, Linn.
Rubus discolor, W. L. N.
Cratægus Oxyacantha, Linn.
Hedera Helix, Linn.
Lonicera Periclymenum, Linn.
Taraxacum officinale, Wigg.
Erica Tetralix, Linn.
Teucrium Scorodonia, Linn.
Salix caprea, Linn.
Orchis maculata, Linn.

1500 feet (Muskry Lake level).

Caltha palustris, Linn.
Linum catharticum, Linn.
Comarum palustre, Linn.
Spiræa Ulmaria, Linn.
Callitriche verna, Linn.
Galium uliginosum, Linn.
Tussilago Farfara, Linn.
Senecio vulgaris, Linn.
Myosotis repens, Don.
Polygonum Hydropiper, Linn.
Potamogeton polygonifolius, Pour.
Triglochin palustre, Linn.
Narthecium ossifragum, Huds.
Juncus acutiflorus, Ehrh.
Carex præcox, Jacq.
C. ampullacea, Good.
Nardus stricta, Linn.

1400 feet.

Fragaria vesca, Linn.
Scolopendrium vulgare, Sm. (only station).

1350 feet.

Stellaria graminea, Linn.

1300 feet.

Meconopsis cambrica, Linn., big. (to 1200 feet).
Hypericum Androsæmum, Linn. (only station).
Veronica agrestis, Linn.

1250 feet (Slieve Anard).

Ulex europæus, Linn.
Ulex Gallii, Planchon.

1200 feet.

Lychnis Flos-cuculi, Linn.
Sagina procumbens, Linn.
Lotus corniculatus, Linn.
Vicia cracca, Linn.
Sanicula europæa, Linn.
Carduus palustris, Linn.
Scirpus setaceus, Linn.
Lastrea æmula, Brack.

1000 feet.

Trifolium pratense, Linn.
Hydrocotyle vulgaris, Linn.
Senecio aquaticus, Huds.
Pedicularis palustris, Linn.
Scirpus palustris, Linn.
Molinia cærulea, Mœnch.
Equisetum sylvaticum, Linn. (only station).

900 feet.

Drosera rotundifolia, Linn.
Vicia sepium, Linn.
Circæa lutetiana, Linn.
Veronica scutellata, Linn. (only station).

850 feet.

Pinguicula lusitanica, Linn. (only station).

800 feet.

Viola sylvatica, Fries.
Polygala vulgaris, Linn.
P. depressa, Wender.
Lotus major, Scop.
Sarothamnus scoparius, Koch.
Helosciadium nodiflorum, Koch.
Senecio jacobæa, Linn.
Hypochæris radicata, Linn.
Plantago lanceolata, Linn.
Anagallis tenella, Linn.
Juncus effusus, Linn.
Juncus bufonius, Linn.
Aira cæspitosa, Linn.
A. caryophyllea, Linn.
Holcus lanatus, Linn.

700 to 600 feet.

Ranunculus hederaceus, Linn.
Hypericum humifusum, Linn.
Prunus spinosa, Linn.
Gnaphalium uliginosum, Linn.
Rumex nemorosus, Schrad.
P. aviculare, Linn.
And many weeds of cultivation.

LXII.—On Halos and Anthelia. By Philip Burton.

[Read, November 30, 1880.]

The formation of those luminous circles termed halos, and of the other appearances which sometimes accompany them, is now universally attributed to the action of icy particles suspended in the air—an opinion which seems to have been first entertained by Descartes, and was afterwards established by Mariotte and Dr. Young. Of all these appearances, the halo of 22° distance from the sun is the only one which occurs frequently in these countries; it may be said, indeed, to be a very common phenomenon usually preceding changes of weather. Its formation is exemplified by bringing filaments of hoar-frost very near the eye in sunlight, when colours corresponding to those of the halo will appear at the same elongation. A similar circle is seen less frequently at the distance of 46° from the sun, and, according to Cavendish, is produced by the ends of the crystals when they are regularly formed. Parhelia, or "mock suns," occasionally occur about the places where these halos are intersected by horizontal and vertical circles passing through the sun; these are, also, explicable on principles suggested by Mariotte. But other halos have been described which are not so easily accounted for. Thus, on the 1st of December, 1819, Captain Parry observed one which surrounded the moon at a distance of about 38°, and was accompanied by paraselenæ, and it does not appear evident why such phenomena should occur at this particular elongation.

On the 6th of March, 1869, I observed a circular halo smaller than any of the preceding, its semi-diameter, as I considered, not being greater than 10° or 12°. Its colours were in the usual order, the red being next the sun, and it was visible for more than two hours. It could not have been a corona, as such a phenomenon can seldom be seen unless when reflected from water, being generally too faint to be otherwise perceived, whereas in the present instance the halo was very bright. The part of the sky where it occurred was free from clouds, though presenting a sort of hazy appearance; and the estimate which I made of the diameter of the circle showed it to be about half that of the common halo. As calculation shows that prisms of ice whose bases are regular pentagons would produce a halo similar to the ordinary one, and at the distance of 11° 46′ from the sun (which very well agrees with the estimated position), it appears very probable that this circle must have been formed by such crystals. And that water may sometimes be frozen in particles of that shape, I have no doubt, having on one occasion seen a shower of hail which consisted entirely of pentagonal prisms. These were perfectly formed, of a whitish colour, and nearly opaque, and were remarkable for their shortness in comparison

with the diagonals of the bases, thus presenting the appearance of pentagonal plates.

Some varieties of cirrus clouds, though doubtless composed of frozen particles, do not exhibit halos. These are of a whitish colour, and are probably more or less opaque; sometimes, also, they may consist of particles having a globular form (like small snow or hail), which would explain the absence of coloured rings. During a balloon ascent from Paris in 1874, MM. Albert and Gaston Tissandier passed through a zone of ice crystals which extended through a depth of 200 metres, and presented the appearance of a "galaxy of little hexagonal stars;" yet as no coloured circles are mentioned as having been seen, it is to be presumed that they were not visible. In this instance, therefore, the crystals must have been either partly opaque or irregularly formed.

Bright specks of halo appearing at a greater distance from the sun than the parhelia above mentioned are called anthelia. These are of rare occurrence, and though I looked for them on several occasions which I thought favourable to their appearance, I have not discerned them in any instance. Three positions are usually assigned to them, the first being about 90° from the sun. In reference to this appearance Dr. Young says: "The lateral anthelia may be produced by the rays refracted after two intermediate reflections, which will have a constant deviation 60° greater than those which form the halo. These anthelia ought, therefore, to be about 82° from the sun. They are, however, usually represented as much more distant." The explanation here given is doubtless correct; but there seems to be a mistake in assigning 82° as the distance from the sun, that quantity being not the greatest deviation, but its supplement. If x and z be the angles made by the incident and emergent rays with perpendiculars to the respective surfaces, and I = the refracting angle of the prism (not regarding the signs of the angles, and supposing also that in the progress of a ray each change of direction is made from one surface of the prism to the next in succession which is inclined to it at an angle equal to I), then the deviation after two refractions and two reflections will be $3I - (x + z)$. For hexagonal prisms this becomes $180° - (x + z)$, the maximum value of which (corresponding to index 1·31) is 98° 10′. The part of the light which is differently reflected does not form an anthelion at any deviation whatever. Hevelius and others have given 90° as the distance of the anthelia observed by them; but these instances are not conclusive, as the elongations seem to have been merely estimated, and not obtained by measurement.

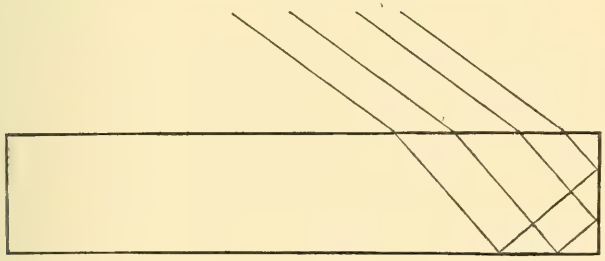
The other positions of the phenomena are mentioned in the following statement:—"The anthelia seem to be referrible to two refractions and an intermediate reflection within the same crystal, causing a deviation of about $120 + 22 = 142°$; and sometimes with two intermediate reflections producing an angle of $60 + 22 = 82°$ only. It is not very easy, however, to assign a reason for the appearance of an anthelion exactly opposite to the sun, which is said to have been sometimes seen in the horizontal circle."—(*Encyclopædia Britannica*, vol. vi., p. 645.)

Here it is evident that the deviation, 142°, has been calculated for rays whose paths within the crystals make equal angles with the surfaces, but no reason has been adduced to show that these could form an anthelion or halo. When light is once reflected in any regular prism (in the manner before mentioned), the deviation is $180° - 2I + (x + z)$, which, since in this case z is always equal to x, reduces to $180° - 2I + 2x$. Now, as this quantity must vary twice as fast as x, it cannot tend to become constant for any successive values thereof; from which it follows that there cannot be at any point such a spissitude of the homogeneous rays as is always requisite to form halos. Thus it appears that no halo or anthelion can be caused by light which has been only once reflected.

An anthelion not differing much from the assigned position would be produced by two refractions and two reflections in quadrilateral prisms having right angles. The deviation in this case is $270° - (x + z)$, which, when a maximum, gives 134° 16′, the elongation of the anthelion formed by such crystals; hence it appears probable that the phenomena seen near this position were produced by rectangular prisms, or by the ends of the usual hexagonal ones.

If the colours of these phenomena were observed, their order with respect to the sun would sufficiently indicate whether they were formed by rays directly transmitted, or after two reflections. In the former case it is evident that the deviation must be a minimum, and in the latter a maximum, and the colours of the reflected anthelion will be the reverse of those usually seen in halos; but I have not found them described in any instance.

The third anthelion which appears opposite to the sun has not been explained; but it seems possible that a phenomenon of this kind may sometimes be produced by part of the light which has been twice reflected in rectangular prisms. If at each change of direction a ray passes from one surface of such a prism to the next, or again, if the



reflections be made at the two opposite surfaces which are adjacent to that at which the light was first incident, the deviation will be $3I - (x + z)$ as before. But it is easily seen that a portion of the light may be so transmitted that after the second reflection it will again fall

upon the surface at which it entered the crystal, the rays then emerging in parallel lines. In this case it is evident that the deviation is constant, and equal to 180°; hence, whatever be the angle of incidence, the light will return in the same direction, and thus an indefinite number of crystals will contribute to the formation of an anthelion opposite to the sun. This may happen whether the principal section of the prisms be square or oblong, and it may also take place in hexagonal prisms, since a section of any of these made by a plane perpendicular to two opposite surfaces and to the bases will have the form of an oblong. But as the position of the anthelion thus formed would be at or near the antisolar point, it could only occur at a low altitude; hence it would not explain the appearances which have been seen at considerable heights. Mr. Barker has described one seen near Lake Superior, which had an altitude greater than 45°, or above twice that of the sun (*Philosophical Transactions* for 1787, p. 44). The horizontal circle which was in that instance so high is usually represented as passing through the sun.

LXIII. ABNORMALITIES IN HUMAN MYOLOGY. By J. F. KNOTT, F.R.C.S.I.

[Read, April 11, 1881.]

THE following is an imperfect list of the muscular anomalies which have come under my notice during the four winters which I have occupied the office of Demonstrator of Anatomy in the School of the Royal College of Surgeons. During that time I have paid particular attention to some of those which struck me in the commencement as being specially important or interesting, and which attracted my attention sufficiently to induce me to tabulate the frequency of their occurrence. As I had not the advantage of any co-operation in the research, a very large proportion of the anomalies which might easily have been preserved were necessarily lost, from the fact that it was impossible for me to distribute my attention over the dissection of so large a number of subjects as were always passing through the room. My statistics are, accordingly, in many instances, very imperfect, although by no means so, I hope, in all; but, although not so valuable as could be desired as an index of frequency, I venture to hope that the publication of the present collection will be found interesting to those who have devoted any attention to this special department of Anatomy. The importance attached to these variations must daily increase in connexion with the absorbing interest of the study of muscular morphology, and of the homologous elements thereof in the various grades of the animal kingdom. Viewed from this standpoint, an otherwise somewhat dry catalogue of variations in Human Myology will be looked upon with favour by those who hail with welcome the addition of every small contribution to the hourly increasing treasury of our knowledge in this, one of the most interesting departments of human study.

Occipito-frontalis.—The early removal of the brain prevented me from examining this muscle completely, in a large proportion of the subjects of our dissecting-room. The frontal portion I have seldom found to agree completely with the description given in our standard text-books. I have noted its peculiarities in twenty-eight cases, in which I examined it with special care. In only five of these did the fleshy fibres reach so high as the coronal suture. Below I have always found its fibres attached to the internal angular process of the os frontis, some being continued into the pyramidalis nasi, and levator labii superioris alaeque nasi, but the great bulk of the fibres blended with the orbicularis palpebrarum and corrugator supercilii, and a large proportion adhered to the deep surface of the skin of the eyebrow. I could never satisfy myself of an attachment of any of its fibres to the nasal bone, glabella, superciliary ridge, or supra-orbital arch, as has been described by different observers. In every case I examined, the deep surface of the muscle appeared to glide freely over those bony prominences, and to be connected thereto

merely by loose areolar tissue. In one case a slip was found connected to the upper margin of the tendo oculi. In three examples there was a well-marked decussation of the lower fibres of the frontal portions of opposite sides. In many instances the muscle was found in an extremely atrophic condition, and in a large proportion its fibres were found split up into fasciculi, but in no case was it completely absent, as in the example noted by Professor Macalister.

Of the *occipitalis* muscle I have seen union of those of opposite sides in two instances, and decussation of the lower fibres in one case.

Transversus nuchae (F. E. Schultze).—Was present on both sides in five of the twenty-eight bodies, and on one side only in two others. The muscle is said to be always symmetrical, but in the latter instances I could find no muscular fibres on the opposite side, but a small transverse tendinous band took its place. The attachments were the same in all: from the external occipital protuberance, on the inside, to the posterior border of the sterno-cleido-mastoid muscle at its insertion; while a few fibres were attached separately to the superior curved line of occipital bone above the others.

Of the muscles of the ear, intrinsic or extrinsic, although frequently examined, I have not noted the variations with any regularity.

Retrahens aurem.—This muscle I have seen usually formed of two very distinct slips, and somewhat less frequently of three fasciculi, a condition which was looked upon by Albinus as the normal arrangement (*tres retrahentes auriculam*). The lowest of the three bundles I have found arising in two instances from the cervical fascia over the upper part of the sterno-cleido-mastoid muscle. In a few cases one of the bundles was found replaced by a tendinous band.

Attollens and *Attrahens aurem* I have frequently found meeting at their adjacent edges so as to form one continuous plane of muscular fibres, as described by Cruveilhier (*muscle auriculaire superieur ou auriculo-temporal*). The origin of attrahens aurem from the zygoma, described as normal by Wharton, Jones, and Harrison, I have met with in eight cases. Cruveilhier describes this as a distinct muscle under the name of *muscle auriculaire anterieur profond*, whose posterior attachment is into the external surface of the tragus.

The intrinsic muscles of the auricle have so often eluded my attempts to define them, that I do not think I succeeded in any one case in demonstrating the presence of all of them in the same subject.

Depressor auriculae (Lauth); *stylo-auricularis* (Hyrtl).—Of this muscle I found one example. In three other cases I was able to define a well-marked fibrous cord, having the direction and attachments presented by the muscular fibres when present. In my case the origin was in common with that of the stylo-glossus muscle, and the insertion into the cartilaginous part of the external auditory meatus.

The muscles of the tympanum and the internal muscles of the orbit I have not examined with a special view to variations in attachment. An accessory slip to the obliquus oculi superior (*comes obliqui superioris; obliquus accessorius; gracillimus oculi; gracillimus orbitae*) I have

twice seen. In one case the origin of the anomalous bundle of muscular fibres was in common with the levator palpebrae superioris, and the insertion into the fibrous pulley for tendon of superior oblique (*rectus quintus* of Molinetti; *tensor trochleae* of Budge).

Depressor supercilii (Lesshaff); *depressor palpebrarum* (Arlt); *lachrymalis anterior* (Henke).—Of this muscle the fibres were found moderately well developed in two cases out of seven in which it was looked for. In the others it was almost completely absent: a few fibres were found with difficulty in two of them.

Depressor palpebrae inferioris (Caldani).—This muscle, which seems to be a continuation of some of the fibres of the platysma myoides, I have been able to define clearly in five out of eighteen cases in which it was searched for, the upper extremity being attached to the lower fibres of the orbicularis palpebrarum.

Orbicularis palpebrarum.—A slip from this muscle to the levator palpebrae superioris is described by Henle and noticed by Professor Macalister. I consider it to be a not uncommon arrangement, as I have found it developed in a considerable number of instances, although I did not take any note of the proportion. The origin of the zygomaticus minor from the lower fibres of the orbicularis I have twice observed.

Levator labii superioris.—The only deviation from the usually accepted description of this muscle which I have met with is the tricipital arrangement described by Eustachius, the outer coming from the malar bone (*caput zygomaticum, jochbeinzacke* of Henle). This bundle of fibres was well developed in about one-third the cases examined.

Depressor septi mobilis narium (Meyer, Krause), *depressor apicis naris, nasalis labii superioris, nasolabialis*—looked upon by many as merely a septal attachment of the *orbicularis oris,* has been more correctly described by Meyer as a separate muscle of triangular form. The base is below, blending with the upper fibres of the orbicularis oris, and apex above, attached to the lower border of the septal cartilage.

Risorius (Santorini).—The typical arrangement of the fibres of this muscle—from parotidean fascia to angle of mouth, blending with orbicularis oris—is met with in a large proportion of cases. The fibres in their inward course pass superficial to those of the platysma myoides, and form with the latter an acute angle. The risorius of most of our text-books of the present day is derived from the platysma itself, but the description is I think rather a loose one, and not borne out by the results of careful repeated examination. Rarer origins have been described—from the zygoma (M'Whinnie); external ear (Albinus): fascia over upper third of sterno-cleido-mastoid (Hallett); an accessory head from transversus nuchae (F. E. Schultze)—of each of these I have met with examples.

Transversus menti (Santorini); *faisceau sous-symphysien* (Cruveilhier).—This band of muscular fibres prolonged from the antero-internal part of the triangularis menti, meets a similar one from the opposite side in the mesial line. On its presence the existence of a "double-chin" depends. I have found it in three cases out of eleven in which it was

searched for. From its peculiar action on the contour of the submental region, it has been called by German authors the *doppelkinnmuskel.*

Masseter.—The only anomaly I noticed in connexion with this muscle was a coalescence of its deeper fibres with the lower fibres of the temporal. This condition has been also observed by Professor Macalister, and I have met with it three times. The *bursa masseterica* described by Monro between the two parts of this muscle I have failed to find, although I have carefully examined the muscle for this special purpose in thirty subjects. Of the bursa described by Hyrtl between the deep part of the muscle and the capsule of the temporomaxillary articulation I have met several examples.

Buccinator.—A few fibres of this muscle I have seen to arise from Steno's duct in three instances.

Pterygoideus proprius (Henle, Gruber, Theile, Macalister).—Of this muscle I have met with three examples in one hundred and twelve bodies, passing as usual from the crest on the great wing of sphenoid to posterior edge of external pterygoid plate.

Sterno-cleido-mastoideus.—Of this muscle I have met with many anomalies, in some cases completely divided into sterno-mastoid and cleido-mastoid: of this I have met with eleven examples. The cleido-mastoid I have found in three cases divided into two completely separate superimposed laminae, distinct to the mastoid attachment. In five cases I have seen the upper sternal fibres of the pectoralis major taking an accessory tendinous origin from the outer edge of the sternal head of this muscle.

Levator claviculae (Wood).—Of this muscle I have seen one very well developed specimen attached at its upper end to anterior tubercles of transverse processes of second, third, and fourth cervical vertebrae, and below to the middle third of upper border of clavicle outside the cleido-mastoid.

Coraco-cervicalis (Krause, Hallett).—Of this muscle, which is no other than the posterior belly of omo-hyoid terminating in the cervical fascia—when the anterior belly is absent—I have met with two examples. I have in another case traced a small aponeurotic slip from the upper edge of the tendon formed by posterior belly of omo-hyoid, along the normal course of anterior belly to the body of the hyoid bone.

Omo-hyoid.—Of the origin of the posterior belly of this muscle from the coracoid process I have met with seven examples (*coraco-hyoid* of Gruber). In one case the origin of this belly was from the acromion process. (Origin from first rib as described by Wagner and Gruber I have never seen.) Of the purely clavicular origin I have met with two specimens; in each case the muscle was monogastric, and presented at the level of the normal tendon merely a few longitudinal tendinous fibres on its deep surface (*cleido-hyoid* of Schmidtmüller). In addition to the variations above described under the head of the musculus coraco-cervicalis I have found in two other cases the anterior belly represented by *two* distinct tendinous slips passing from the normal tendon up to body of hyoid bone.

Crico-corniculatus (Tourtual): *kerato-cricoid* (Merkel): *crico-thy-*

reoideus posticus (Bochdalek).—Of this muscle I have found seven cases of unilateral development, and two others in which its fibres were symmetrical.

Crico-epiglotticus.—Under this name has been described a bundle of muscular fibres often found (thirty-four per cent., Krause) arising from the inner surface of cricoid cartilage, and passing upwards beneath the mucous membrane to the margin of the epiglottis. I have been able to define it three times in nineteen subjects. It was bilateral in each case. Sometimes a similar bundle terminates in the arytaeno-epiglottidean fold of mucous membrane forming a crico-membranosus.

Crico-trachealis.—Of this anomalous muscle I have met with one specimen on the left side of the body of a female subject. It came from lower border of cricoid cartilage, approaching close to the median line in front, and having a breadth of about half an inch above; it gradually narrowed as it passed down to its insertion into the fourth and fifth rings of the trachea behind the isthmus of the thyroid body.

Thyreo-trachealis (Gruber); *thyreo-trachealis profundus* (Krause).—From lower border of thyroid cartilage to upper part of trachea. This band of muscular fibres I found three times in twenty-eight subjects in which its existence was specially searched for. The muscle was symmetrical in one case; in the others single; in both on left side. The inferior attachment varied in all. In one case the insertion was into the third ring of the trachea; in another into third and fourth. In the case in which the muscle existed on both sides the insertion was into the fourth and fifth rings on one side (the left); on the other into the fifth ring alone.

Thyreo-syndesmicus (Sömmerring).—From superior corner of thyroid cartilage to posterior border of thyro-hyoid ligament. In one subject I found this small anomalous band of muscular fibres present on both sides. I have met with no other example.

Thyreoideus transversus anomalus (Gruber) (s. *impar*); *thyreoideus marginalis inferior; incisurae* (*cartilaginis thyroideae*) *mediae transversus.*—This band of muscular fibres crosses from one side of lower border of ala of thyroid cartilage to the other, lying in front of the upper part of the crico-thyroid membrane. I have met with two examples.

Thyreo-corniculatus.—Fibres arising in common with the upper fibres of thyreo-arytaenoideus, and passing obliquely upwards and backwards to the cartilage of Santorini. A bundle of fibres answering to this description I have met with in two cases out of nineteen in which they were sought for with special care. A similar bundle of fibres going to the cartilage of Wrisberg has been described under the name of—

Thyreo-cuneiformis.—This I have not seen.

Thyreo-epiglotticus inferior (s. *major*) and *superior* (s. *minor*).—Two very thin laminae of muscular fibres arising from inner surface of thyroid cartilage, and ascending to the adjacent margin of the epiglottis, some blending with upper fibres of arytaeno-epiglottideus. *Inferior* frequently takes some fibres of origin from upper border of thyro-arytenoideus. I have found one or both of these strata in about one-half of the cases in which they were carefully sought for before

decomposition had advanced too far, but always in an extremely atrophic state. Those fibres, which go directly to the margin of the epiglottis itself, have also been described under the name of *musculus epiglottidis* (*reflector* s. *depressor epiglottidis*.)

Thyreo-epiglotticus longus (C. Krause).—This band of muscular fibres I have found in two cases out of twenty-seven in which it was carefully sought for. Arising from inner surface of ala of thyroid cartilage, immediately above the incisura thyreoidea inferior lateralis, it passes upwards on the outer side of the thyreo-arytaenoideus, to be inserted with the fibres of the thyreo-ary-epiglotticus into the corresponding lateral margin of epiglottis.

Thyreoideus internus; sub-thyreoideus (Krause).—According to this author, a muscular bundle may be found in from 15 to 20 per cent. of all cases examined, passing from lower margin of ala of thyroid cartilage, near the middle line, backwards to the posterior attachment immediately above the root of the inferior cornu. I have found it twice in forty-three bodies.

Thyreoideus proprius (Krause).—The name has been applied by this author to a delicate layer of muscular fibres lying on the inner surface of the thyroid cartilage, and reaching from the incisura superior nearly to the inferior margin. In their descent they interlace with the other internal muscles. I have in a few cases found a small number of scattered vertical fibres in this situation, but never so arranged as to form a distinct layer.

Syndesmo-thyreoideus.—This name has been applied to a small muscle found in very rare instances (one per cent. according to Krause) passing from upper part of inner surface of thyroid cartilage to posterior thyro-hyoid ligament. I have met with it twice: in one subject it was symmetrically developed on both sides.

Kerato-arytaenoideus (*schildknorpelhorn-giessbeckenknorpels-muskel* of J. Gruber).—Arises from posterior border of inferior cornu of thyroid cartilage, and is inserted into the muscular process of the arytaenoid. I have found four examples.

Other anomalous laryngeal muscles have been described by many writers—such as the *hyo-epiglotticus* (Fabricius); *crico-epiglotticus* (Verheyen); *glosso-epiglotticus* (Eustachius); but I have never met with a specimen of any of them.

Digastric.—The only noteworthy anomaly of this muscle I have met with is a doubling of the anterior belly, the anomalous slip going to the median raphe of the mylo-hyoid muscles. Once I have found it symmetrical, the two supernumerary slips meeting in the mesial line, and in three other cases the anomaly existed on one side only.

Mento-hyoid (Macalister).—Of this muscle I have met with four examples. In all it lay superficial to the anterior belly of digastric, as it passed from front of body of hyoid bone to lower border of inferior maxilla. In one instance it was symmetrically developed.

Mylo-hyoideus.—The only remarkable variation I have seen in the attachments or relations of this muscle was a perforation of the posterior part by Wharton's duct, which came under my observation twice.

Genio-hyoideus.—I have in a good many cases found this muscle inseparably blended with the lower fibres of the genio-hyo-glossus.

Mylo-glossus (Rolfincius).—Of this muscle I have met with one example, passing in its usual direction from angle of jaw to side of base of tongue.

Stylo-glossus.—In five instances I have found this muscle with an accessory head from the stylo-maxillary ligament. Twice I have found it completely absent on one side.

Stylo-hyoideus.—In several instances I have seen the two parts into which this muscle was split by the tendon of the digastric separate from the origin to the insertion. I have seen the muscle inserted into the tendon of the digastric in one case. One instance of complete absence was noted.

Triticeo-glossus (Bochdalek, Macalister).—This anomalous bundle of muscular fibres I have succeeded in defining but five times in forty-four cases in which it was carefully sought for. This is much below the average of frequency which occurred in the experience of Bochdalek (8 in 22), and Macalister (1 in 6). Professor Krause makes the proportion of cases in which it occurs to vary from 17 to 36 per cent.

Azygos linguae; musculus longitudinalis linguae inferior medius (Bochdalek).—A small median bundle of longitudinal fibres found between the genio-hyo-glossi muscles in the posterior fourth of the tongue. I have been able to define it in five bodies out of forty-seven in which it was sought for.

Genio-glossus accessorius (Luschka).—A bundle of the lower fibres of the genio-hyo-glossus—from lowest part of genial tubercle to hyoid bone. I have succeeded in defining such a bundle as Luschka describes, separated from the other fibres of the genio-hyo-glossus about once in seven subjects.

Cephalo-pharyngeus (Sandifort).—Of this anomalous band of muscular fibres I have seen a good many examples:—Three arising from vaginal process of temporal bone; two from petrous portion of temporal bone (*petro-pharyngeus*) inside the inferior opening of the carotid canal; two from the spinous process of the sphenoid; one from the cartilaginous portion of Eustachian tube (*salpingo-pharyngeus*). In the majority of instances the fibres became united to those of the superior constrictor of the pharynx. In two examples they could be traced directly to the inferior constrictor.

Genio-pharyngeus (Winslow).—A slip closely connected along the anterior part of its course with the genio-hyo-glossus, and passing backwards to the side of the pharynx with the fibres of the superior constrictor. I have found several examples.

Syndesmo-pharyngeus.—This name has been given to a small fasciculus of muscular fibres passing from the posterior border of the thyro-hyoid ligament backwards to the median line (*linea alba*) of the pharynx. It bridges over the space intervening between the origins of the middle and inferior constrictors. I have found it twice in forty-seven subjects in which it was specially sought for.

Levator glandulae thyroideae lateralis.—Under this name Krause

mentions a few fibres of the inferior constrictor of the pharynx which take origin from the side of the thyroid body. He says it is present in about one per cent. of subjects examined. I have not been so fortunate as to meet with a specimen.

Azygos pharyngis (Meckel); *solitarius pharyngis* (Santorini).—Under this name Meckel describes a small muscle, usually mesial and single, rarely bilateral and symmetrical (Ketel, 1870), passing from the pharyngeal spine on the basilar process of the occipital bone downwards for a variable distance along the median raphe of the pharynx, into which it is inserted. It is seldom more than half an inch in length. I have found it four times in eighty-seven subjects: once bilateral.

Pharyngo-mastoideus (Ketel).—Arises from the anterior and inner aspect of the mastoid process, and passes inwards between superior and middle constrictors of pharynx to its insertion into the lateral wall of the tube, blending with the fibres of these muscles. I have met with three examples.

Salpingo-pharyngeus (Sandifort).—A muscular fasciculus passing from Eustachian tube to side of pharynx behind the palato-pharyngeus. I have met with one example.

Scalenus anticus.—I have occasionally seen this muscle taking a vertebral origin more or less than that usually described. The only other remarkable peculiarity I have ever observed is, that in two instances I found the phrenic nerve piercing its fibres.

Scalenus medius.—The superior attachment of this muscle, as Krause has correctly pointed out, is from the anterior, *not the posterior* tubercles of transverse processes of the cervical vertebrae, as other anatomists describe it. The usual number is six—all excepting the atlas—but I have found the number to vary from three, the smallest, to all, seven. In one case I found it attached below to the second rib only. In a very large proportion of subjects I found its vertebral attachment quite inseparable from the scalenus posticus.

Scalenus posticus.—In only two instances did I observe any notable anomaly of this muscle. One was complete absence. The other was attachment of lower end to third rib.

Scalenus minimus (Albinus).—The usual origin of this muscle is from the anterior tubercles of transverse processes of fifth, sixth, and seventh cervical vertebrae, behind the attachment of anterior scalenus, to which it is often inseparably adherent. Its inferior extremity is connected to the second rib. Macalister makes the relative frequency of its presence three times in seven subjects, and "oftener present inseparably united to the other scalenes." Krause gives a proportion of forty-two per cent. I have not been able to find it in so large a proportion of cases: it was well defined five times in twenty-three bodies.

Scalenus lateralis (Albinus); *musculus costo-transversalis.*—This muscle arises from the transverse process of the seventh cervical vertebra, and passes downwards between the middle and posterior scaleni and a little outside the latter (of which it would seem to be a detached portion) to its inferior attachment to second rib. I have found it

four times: it was present in two of the twenty-three subjects in which the scalenes were specially dissected.

Scalenus accessorius.—Arises from the posterior tubercles of transverse processes of the cervical vertebrae from the fourth to the sixth (Macalister), from fourth to seventh (Krause), and is inserted into the first rib close to the scalenus medius, of which it seems to be a differentiated portion. It is separated from the latter muscle by part of the brachial plexus.

Transversalis cervicis anticus longus colli accessorius (Luschka); *scalenus anticus proprius colli* (Krause).—This rare muscle arises from the anterior tubercles of the transverse processes of the cervical vertebrae, from the seventh to the fourth, and passing upwards is attached to the anterior surface of body of axis immediately below the superior articulating surface, and to the front of the base of the transverse process of the atlas. It is placed posterior to the rectus capitis anticus major. I have met but one example of this muscle.

Transversalis cervicis anticus (Retzius).—Arises from the oblique processes of the cervical vertebrae, from the sixth to the fourth; being intimately connected to the longus colli, and passing upwards is inserted into the upper three cervical vertebrae. Of this rare muscle I have met with two specimens. One had the attachments described by Retzius; the second was attached by its upper extremity to the axis alone, just below and outside the superior articular surface.

Transversalis cervicis medius (Krause).—Of this extremely rare muscle I have never met with an example. Krause has found it attached to the front of the transverse processes of the cervical vertebrae, from the second to the sixth or seventh.

Transversalis cervicis posticus minor; trachelomastoideus minor; trachelomastoideus accessorius.—Arises from transverse processes of vertebrae, from the second dorsal to the fifth cervical, and ascending to its insertion is attached above to the transverse process of the atlas, and mastoid process of the temporal bone. I have noted one specimen.

Rhomboideus occipitalis (Murie, Mivart); *occipito-scapularis* (Wood).—Arises from the internal third of the linea semicircularis media ossis occipitis, above the attachment of the complexus, and is inserted into the scapula, above the rhomboideus minor. I have met with three specimens of this muscle.

Levator claviculae (Wood); *cleido-cervicalis superior; trachelo-clavicularis superior.*—The clavicular attachment of this muscle is either to the middle third of the bone, or to its acromial extremity. The upper is more variable in its points of fixation. It has been found attached to the transverse process of the atlas (*cleido-atlanticus*); to that of the axis (*cleido-epistrophicus*); to the oblique processes of the fourth and fifth cervical vertebrae (*cleido-cervicalis inferior; scalenus anticus accessorius*); to the transverse process of the sixth alone (*cleido-cervicalis imus*). It has also been found attached to the transverse process of the third cervical vertebrae. The lower has, in some instances, been seen to blend with the trapezius. I have met with two specimens of the cleido-cervicalis imus, and one of the cleido-epistrophicus. Another

specimen I have found attached above to the oblique processes of the third, fourth, and fifth cervical vertebrae, and inserted below into the middle third of upper border of clavicle.

Rhombo-atloideus (Macalister, 1866); *splenius accessorius* (Krause); *adjutor splenii* v. *m. singularis splenius accessorius* (Walther).—This muscle passes from the spinous processes of the last cervical or first dorsal vertebra—where it arises beneath the rhomboideus minor—to the transverse process of the atlas. It has been found attached to the sixth and seventh cervical spines, or to the seventh alone, or to the first and second dorsal spines, or to the second and third. I have found three examples in which the muscle arose from the last cervical and first dorsal spines, and one in which it arose from the three upper dorsal. In two cases the origin was from the two upper dorsal vertebrae. Mr. Wood found it three times in thirty-six subjects, and Krause gives eight as its percentage of frequency. I have found it six times in seventy-five subjects.

Atlanto-mastoideus.—Arises from transverse process of atlas, and is inserted into the posterior border of the mastoid process of the temporal bone. Krause makes its relative frequency to be thirty per cent. of subjects examined; this is much greater than what has occurred in my experience, as I have found it but four times in thirty-three subjects which were carefully examined for it.

Rectus capitis anticus major, . . . minor.—Doubling of these muscles I have pretty often observed, but have kept no account of the relative frequency.

Rectus capitis lateralis accessorius (Winslow).—This muscle, a doubling of the normal rectus capitis lateralis, I have found three times in thirty-three subjects in which it was specially sought for.

Pectoralis major.—The three parts of this muscle I have found completely distinct in four instances. The clavicular, sternal, and costal portions could easily be differentiated even down to their very insertion into the humerus. In two cases I have seen an accessory slip to the short head of the biceps taking origin from the lower border of the tendon. In one case the tendon divided into two parts, between which passed the long tendon of the biceps, one lamina going to either lip of the bicipital groove.

Pectoralis major accessorius.—Arises from the costal cartilages, from the first or second to the sixth or seventh, and passes outwards beneath the deep fibres of the pectoralis major to join the tendon of insertion. It is but a complete differentiation of the costal portion of the pectoralis major.

Chondro-epitrochlearis.—Of this muscle I have met with four specimens. The attachments were the same in all cases. The origin was from the sixth costal cartilage, and the fibres were placed in close apposition with the lower fibres of the pectoralis major. The insertion was into the brachial aponeurosis at the lower fourth of the arm on its inner aspect—one sending a slight tendinous slip down to the epitrochlea. So that the muscle in all these cases better deserved the name of *chondro-fascialis.*

Pectoralis minor.—In five cases I have seen the tendon of this muscle send a strong slip over the coracoid process to pierce the coraco-acromial ligament, and blend with the capsule of the shoulder-joint. In one instance the whole tendon wound over the coracoid process, and divided into two strong bands; one went to the margin of the glenoid cavity, the second to the greater tuberosity of the humerus.

Pectoralis minimus (Gruber).—Arises from anterior surface of manubrium sterni, rhomboid ligament, and cartilage of first rib, and passes outwards in front of the costo-coracoid membrane to be inserted into the inner border of the coracoid process of the scapula. It sometimes arises from the cartilage of the first rib alone, and such was the origin of the muscle in the two examples which I have met with.

Pectoralis quartus.—Arises from the fascia over the lower part of the serratus magnus, and occasionally from the adjacent portions of one or more ribs, and is inserted into the lower border of the tendon of the great pectoral, or into the oschelbogue of Lauger.

Subclavius.—This muscle I have found completely absent in two instances. In both the deficiency was on the left side.

Supra clavicularis proprius, v. *tensor fasciae colli* (Gruber); *anomalus claviculae.*—Of this muscle I have met with two examples, one of which has been already recorded (vide *Journal of Anatomy and Physiology*, xv. 139).

The second specimen (observed during the last winter session) had similar attachments, but was much smaller.

Acromio-clavicularis, v. *praeclavicularis lateralis* (Gruber).—Consists of a few muscular fibres passing from the outer third of the clavicle to the tip of the acromion. I have, on one occasion, seen a small band of fibres in situation so very delicate as hardly to deserve the dignity of a special name. It lies superficial to the upper fibres of the deltoid.

Omo-clavicularis (*coraco-clavicularis*, v. *coraco-clavicularis posticus*, Calori, Gruber).—This muscle arises from the outer end of the clavicle, less frequently from the inner end, sometimes also from the manubrium sterni, and passes outwards to be inserted into the coracoid process of the scapula. The insertion is sometimes into the upper border of this bone. A similar muscular band has been described by Mr. Wood under the name of—

Scapulo-clavicularis.—This I have never succeeded in finding, although I have sought for it in more than a hundred and twenty subjects.

Sterno-clavicularis; sterno-clavicularis anticus; prae-clavicularis medius (described and named by Gruber).—Arises from manubrium sterni, anterior sterno-clavicular ligament, and cartilage of first rib—sometimes from only one of these points of attachment—and passes outwards in front of the subclavius to be inserted into the middle third of the clavicle. It has been found inserted into the coracoid process of the scapula, when it received the name of—

Coraco-clavicularis anticus, v. *singularis.*—Of the latter insertion

I have met with one case. I have never seen the more frequent form of this anomaly.

Supra-clavicularis; sterno-clavicularis (Hyrtl); *sterno-clavicularis superior; sterno-omoideus.*—Arises from anterior surface of manubrium sterni, and is inserted into the front of the clavicle at a variable distance from its outer end. When symmetrically developed, the two muscles often meet in the middle line, forming a

Musculus interclavicularis.—Of this latter form of the anomaly I have seen two examples. I have observed but one specimen of unilateral development.

Retro-clavicularis (Weber); *sterno-clavicularis posticus.*—Arises from posterior surface of manubrium sterni, and is inserted into the inner end of the clavicle, on its posterior surface. I have seen one specimen, but it had, as in the one observed by Lawson Tait, a second head from the posterior sterno-clavicular ligament.

Infra-clavicularis (Bardeleben).—Arises from front of clavicle, and is inserted into the fascia in front of the pectoralis major. I have met with one example: it arose fleshy from the clavicle for about an inch of the middle of its anterior border and formed a tendinous expansion, which, passing downwards and outwards, and intersecting, at a very acute angle, the line of direction of the clavicular fibres of the pectoralis major, bended with the fascia, in front of the latter muscle, after a course—including the length of the fleshy fibres—of about four inches. So far as I know, this is the only example published, except that of Bardeleben.

Subclavius posticus; scapulo-costalis; sterno-scapularis.—Arises from the first rib, and is inserted into the root of the coracoid process of the scapula, or into the ligament of the notch. I have seen but one example occurring in a large number of subjects, having examined this region carefully for anomalies, in over a hundred. Krause says the frequency of its occurrence averages seven per cent., and according to Professor Macalister it is met with once in fifteen subjects.

Supra-costalis superficialis (vel *anterior*).—A bundle of muscular fibres passing from one of the upper ribs (generally the first) to another rib at a variable distance below. It lies beneath the pectoralis major and minor.

Supra-costalis profundus.—This bundle of fibres, when present, lies beneath the serratus anticus magnus. I have met with a good many specimens of both *superficialis* and *profundus*, but did not feel sufficiently interested in the anomaly to keep any record of them.

Transversus colli (Luschka); *costo-fascialis cervicalis* (Macalister).—This muscle arises from the first rib, and passing obliquely inwards behind the clavicle, and between the sterno-hyoid and sterno-thyroid muscles, is inserted into the deep fascia at the root of the neck (septum thoracico-cervicale). Professor Krause suggests that it may be regarded as an upper differentiated digitation of the triangularis sterni muscle.

Tensor semivaginae articulationis humero-scapularis (Gruber).—This

rare muscle arises from the front of the manubrium sterni and cartilage of first rib, and passes outward between pectoralis major and minor, to be inserted into the front of the capsule of the shoulder-joint. I have found on one occasion a bundle of fibres arising from the cartilage of the first rib at its junction with the bone, and passing outwards between the greater and lesser pectoral muscles, to be inserted into the anterior aspect of the shoulder capsule.

To the anomalies of the muscles of the back, of the diaphragm, and of the flat muscles of the abdomen I have not given special attention, although some remarkable deviations from the typical arrangement have been met with.

Basio-deltoideus; fasciculus infraspinata deltoideus (Gruber).—This bundle of fibres is accessory to the normal deltoid muscle, and corresponds to the abductor brachii inferior of the lower mammals (W. Krause, *Anatomie des Kaninchens*, 1868). It arises from the vertebral border of the scapula at a variable level, sometimes as low down as the inferior angle of the bone, and passes outwards to join the lower fibres of the deltoid. Of this form of the accessory muscle I have met with two examples. Other accessory bundles have been described. One from the axillary border of the scapula has been named *costo-deltoideus:* a separate slip from the acromial end of the clavicle has been named *acromio-clavicularis lateralis.* Still rarer specimens are those which have been described under the names of *tensor fasciae deltoideae a fascia infraspinata* and *tensor fasciae deltoideae a margine axillari scapulae,* respectively. I have never met with any of these latter forms.

Infra-spinatus.—This muscle I have twice seen to receive an accessory slip from the deltoid. I have seen a good many specimens (over five in number) in which it was quite inseparable from the teres minor. The upper fibres of the muscle are sometimes quite separate from the remainder, forming what has been described as the *infra-spinatus minor.* Of this variety I have seen one well-defined example.

Teres minor.—Fusion with the infra-spinatus has been already mentioned. Complete absence of the muscle I have once observed.

Teres minimus.—Under this name has been described a bundle of fibres parallel to and in close contact with the lower edge of the teres minor. I have seen one example occurring on both sides of a male subject of great muscular development.

Subscapularis minor; subglenoidalis; infra-spinatus secundus; subscapulo-humeralis; subscapulo-capsularis.—Under this name has been described an upper detached portion of the subscapularis muscle. Arising from the upper part of the axillary border of the scapula, sometimes from the tuberculum infra-glenoidale, where it adheres to the long head of the triceps, it passes outwards to be inserted either with the normal subscapular tendon into the lesser tuberosity of the humerus, or what much more frequently happens, into the front of the capsule of the shoulder-joint (*subscapulo-capsularis,* Gruber, Macalister). According to Professor W. Krause, the frequency of its occurrence varies from five to thirty-three per cent. I have found it four

times in thirty-nine subjects, whose bodies were carefully examined for it: three were inserted into the capsule—one into the lesser tuberosity of the humerus. Professor Krause also mentions among the varieties of the sub-scapularis a bundle of fibres arising from the lesser tuberosity or its immediate vicinity, and going to be inserted into the capsule of the joint. It is present, according to him, in about 0·4 per cent. of the cases examined, and has received the name of

Capsularis humero-scapularis.—I have never succeeded in finding it.

Gleno-brachialis (Gruber), arises with the long head of the biceps from the tuberculum supra-glenoidale, pierces with it the shoulder capsule, and is inserted into the humerus. I have once met with it; the insertion was into the inner edge of the bicipital groove about three-quarters of an inch below the lesser tuberosity.

Coraco-brachialis.—The anomalies of this muscle are numerous, and I have met with examples of nearly all those which have been hitherto described, but regret to say that I have kept no record of their relative frequency in my cases. Three conspicuous forms of this muscle have been described by Wood: *brevis*, *medius*, and *longus*.

Coraco-brachialis brevis.—In its more typical form this muscle arises from the apex of the coracoid process, beneath the ordinary coraco-brachialis, and is inserted into the surgical neck of the humerus below the lesser tuberosity. It has been found by Macalister inserted into the tendon of the subscapularis, and sometimes into the capsule of the shoulder-joint (*coraco-capsularis*); he has also found its fibres blending with those of the subscapularis muscle. Under the head of sub-varieties of this anomaly must be classed the following:—

Depressor tendinis subscapularis majoris, vel *retinaculum musculare tendinis subscapularis majoris* (Gruber); *tensor capsulae humeralis; deltoidius profundus*, which arises from the lower border of the tendon of the subscapularis, and is inserted into the surgical neck of the humerus; and

Tensor fasciae et cutis foveae axillaris, which is merely formed by a detached slip of the other inserted into the skin and fasciae of the axilla. I have found examples of all these abnormalities excepting the last mentioned.

Coraco-brachialis medius.—This I have several times found as a distinct muscle. In all it was pierced by the musculo-cutaneous nerve. In two instances I have seen a muscular slip detached from this muscle to join the inner head of the triceps, and crossing in front of the brachial artery.

Coraco-brachialis longus.—This muscle I have found completely separate in only two instances. In both cases the insertion was into the internal brachial ligament about an inch above the epicondyle. In its downward course the muscle crossed over the brachial artery and median nerve.

Biceps brachii.—As the result of very careful examination in the human subject, and comparison of the arrangement of its fibres with the analogous muscle in the lower animals, Professor W. Krause has con-

cluded that it is really made up of four distinct parts, to which he gives the respective names of *coraco-radialis*, *coraco-ulnaris*, *gleno-radialis*, and *gleno-ulnaris*. The two first named form the short head, while the union of the third and fourth segments forms the long or glenoid portion. Although it may be rather difficult for most anatomists to agree entirely with his views, a careful consideration of them certainly tends to throw a good deal of light on the peculiarities of its variations.

Coraco-radialis.—Alone, is present in *Orycteropus capensis*, rhinoceros, echidna, frog, toad, lizard.

Coraco-radialis and *coraco-ulnaris*.—In emys, chameleon.

Coraco-radialis and *gleno-ulnaris*.—In marsupialia, both muscles being quite separate.

Gleno-radialis.—Alone, in nycto-pithecus, stenops, talpa, horse, ruminantia.

Gleno-ulnaris.—Alone, in *Hyrax capensis*, rodentia.

Gleno-radialis and *gleno-ulnaris*.—In pig, monotremata.

Doubling of the heads. I have observed two examples of duplicity of the long head, and one of that of the short.

The two heads of the muscle I have seen separate for the whole length of its course. The long head I have found completely absent in three cases, and the short head in one. The semilunar aponeurosis I have found completely absent in one case. I have twice found an accessory slip from the tendon of the pectoralis minor going to the short head. An accessory slip from brachialis anticus to biceps I have found in three cases of forty-nine subjects, in which these muscles were carefully examined. An additional head between coraco-brachialis and biceps I have found present five times in the same series of bodies. This nearly agrees with the results of Wood and Macalister, who make its relative frequency to be one in ten. In one case I have found two supernumerary heads arising in this region. The upper came directly from the insertion of the coraco-brachialis, from which it arose by a tendinous slip. The other came from a point about an inch lower down, and was adherent to the adjacent margin of the brachialis anticus. Its origin was entirely fleshy. An additional origin from the great tuberosity I have seen in one case. It has also been described by Meckel and Macalister. Under the denomination of supernumerary attachments of the biceps must also be classed the following varieties, which have been described under separate names:—

Brachio-radialis (Gruber, Theile, &c.).—Arises from the humerus between the insertion of the deltoid and the origin of the supinator longus, and passing down close to the outer margin of the biceps, but distinctly separate from the latter, to be inserted with it into the tuberosity of the radius. I have found this muscle extremely well developed in two instances, but it adhered very intimately to the lower part of the muscular portion of the triceps, and almost inseparably to its tendon.

Brachio-fascialis; brachialis accessorius; supinator brevis accessorius

(Struthers).—This slip arises from the inner side of the biceps, and passing obliquely downwards and inwards, crosses in front of the brachial artery, and is inserted into the fascia over the pronator radii teres. Of this anomaly I have met with four examples.

Brachialis anticus.—This muscle I have found in three instances completely cleft from origin to insertion — but its attachments were in other respects quite normal. Continuity of its outer fibres with those of the supinator longus, as described by Wood and Macalister, I have seen in one case, giving rise to the formation of a tunnel through which passed the musculo-spiral nerve with the accompanying branch of the superior profunda artery. An accessory head from coracobrachialis I have seen in two instances. Of its inferior attachments I have seen the following varieties:—sending a slip to the tendon of the pronator radii teres—this I have observed twice; a slip to the supinator longus below the level of the elbow joint—this I have seen occurring on both sides in one subject; a slip to the flexor sublimis digitorum—of which I found one example in a very muscular subject (male).

Brachialis internus minor.—Of this muscle, which is but a detached slip of the brachialis anticus, I have met with three specimens in forty-nine subjects. In two cases it lay on the radial side of the muscle, and was inserted into the radius at the inferior part of the bicipital tuberosity; in one it lay on the inner side of the muscle, and was inserted separately a little below the level of coronoid process.

Triceps brachii.—I have seen few noteworthy variations from the typical attachments of this muscle. Apparent direct continuity of the triceps and anconeus I have several times observed. A distinct slip from the tendon of the subscapularis at its attachment of the lesser tuberosity I have once seen. In two cases of seventeen subjects (which were specially examined for it) I found a bursa between the internal part of the triceps and the ulnar nerve as it lies behind the epitrochlea. (*Bursa mucosa retro-epitrochlearis* of Gruber.) I have noted four examples of the accessory slip from the lower border of the tendon of the latissimus dorsi, described by Professor Halbertsma under the name of *anconeus quintus*.

Another muscular slip has been described under the name of *anconeus quintus* (vel *minimus*); *epitrochleo-anconeus* (of Gruber); *anconeus epitrochlearis* (Wood).—This muscle arises from the back of the inner condyle of the humerus, and is inserted into the olecranon process of the ulna. Its bulk and extent of attachment are very various; according to most authorities it would seem to be present in about a fourth of the subjects examined.

Subanconeus.—The only peculiarity I have met with in this muscle is the frequency of its absence. Indeed I have but seldom been able to define its existence as a separate muscle, and have been led to wonder why it is described in all the hand-books as a separate muscle. Under the head of the anomalies of the triceps extensor cubiti, I would also include the slip described by Gruber under the name of the *levator tendinis latissimi dorsi*. It arises from the coracoid process and

adjacent part of the capsule of the shoulder-joint, and is inserted into the upper margin of the tendon of the latissimus dorsi.

Supinator radii longus accessorius; brachio-radialis accessorius; brachio-radialis brevis (*vel minor*).—Arises with the supinator longus and is inserted a little below the level of the tuberosity of the radius. I have seen one specimen: it is present, according to Krause, in about one per cent. of the bodies examined. The insertion of supinator radii longus I have found double in one case, the upper tendon being attached to the outer surface of the radius about three inches above the level of the styloid process. The radial head passed between it and the lower tendon, which had the normal insertion of supinator longus.

Extensor carpi radialis accessorius (Wood).—Arises from the outer condyle of the humerus below the attachment of the extensor carpi radialis longior, and travels with the latter muscle—passing through the same groove in the posterior annular ligament of the wrist, and goes thence to its insertion into the base of the first metacarpal bone. I have found it once in a muscular subject. The inferior attachment of this muscle may be into the back of the scaphoid bone, or base of first metacarpal, or into both, as it was in my case; or into outer edge of abductor pollicis, or of outer head of flexor brevis pollicis.

Pronator radii teres.—The two heads of this muscle I have found separate through their whole length down to the radial insertion. It occurred in three instances; in one case on both sides. Twice I have seen a third head arising from the ulna about two inches below the level of the coronoid process.

Flexor carpi radialis.—This muscle I have seen in four instances taking an accessory slip from the inner margin of the coronoid process of the ulna. In two of them the median nerve passed between the heads. With regard to its insertion, I agree with Professor W. Krause in making the normal one to be into both second and third metacarpal bones. This I found to be the case in nineteen out of thirty-four specimens of the muscle, in which the attachments were made out with care. In one of these cases the insertion was into the trapezium; in another into trapezium and second metacarpal; in another into third and fourth metacarpal.

Flexor carpi radialis brevis (v. *profundus*); *radio-carpus* (Fano); *radialis internus brevis* v. *minor*, v. *profundus* (Gruber).—One well-developed specimen of this muscle was found among the thirty-four subjects whose fore-arms I specially examined for muscular anomalies. The origin was from the radius outside the flexor pollicis longus, reaching from the lower end of the oblique line down to about the junction of middle with lower third of outer edge of pronator quadratus. Its tendon passed through a separate canal in the anterior annular ligament close to that for the flexor carpi radialis, and divided into two slips, which went to be inserted into the front of the bases of the second and third metacarpal bones. I have met since with two other specimens of this muscle, similar in origin, but neither nearly so well developed. The insertion varied in each case: one was inserted into the trapezium (the true *radio carpus* of Fano); the other was

inserted by two slips into trapezium and base of second metacarpal bone (*radio-carpo-metacarpalis*).

Palmaris longus.—This, which enjoys the distinction of being the most variable muscle in the body, I found absent in four of thirty-four subjects. In one case the deficiency was symmetrical; in the other three unilateral—two on the left side, one on the right. In the case of bilateral absence, the subject was a female, the others were males. A second head from the coronoid process was present in two instances. There was one example in which the fleshy belly was two and a-half inches in length. In one case the tendon was inserted directly into the outer margin of the abductor pollicis, just below its origin.

I have since met with a specimen in which the insertion was into the tuberosity of the scaphoid bone. Also an example of doubling of the muscle, both heads coming from the internal condyle, but the second head lying beneath the other, and not coming from the common tendon. The deep head has received the name of *palmaris longus accessorius* (Krause).

Flexor digitorum sublimis.—Absence of the tendon for the little finger I have observed in three instances. The index flexor I have, in two cases, found quite distinct from the rest of the muscle, from its origin to its insertion.

Flexor carpi ulnaris.—This muscle I have once found wholly inserted into the anterior annular ligament. The palmaris longus was absent.

Flexor carpi ulnaris brevis.—Of this muscle I have met with one specimen. The origin was from the ulna, inside the upper end of the flexor digitorum sublimis, for about two inches in length. It passed through a separate canal in the anterior annular ligament, and was inserted into the base of the fourth metacarpal bone.

Flexor digitorum profundus.—The only notable variety of this muscle I have seen was a complete isolation of the index portion along its whole length. This occurred twice in thirty-four subjects examined; and I have seen some other examples, of which I took no note.

Flexor digitorum profundus accessorius; musculus accessorius ad digitorum profundum (Gantzner).—One example of this muscle I have seen arising from the inner side of the coronoid process; it formed two tendons which went to the middle and little fingers. The tendons pierced the corresponding ones of the sublimis, and were accompanied by very small tendinous bands from the normal flexor profundus.

Flexor pollicis longus.—This muscle received, in two cases of the thirty-four subjects specially examined, an accessory head from the internal condyle. The coronoid head, which in some form was present in eighteen cases, arose separately in nine; in common with the deep head of pronator radii teres, in three; closely adherent to the coronoid head of flexor sublimis digitorum, in four; and by a slip common to all three in the remaining two. An accessory slip, coming directly from the fleshy fibres of the flexor sublimis digitorum, was present in one case; and such a muscular bundle is mentioned by Krause under the name of *fasciculus exilis*.

Pronator radii quadratus.—Complete separation into two parts

occurred twice in thirty-four subjects, and I have seen several other examples. The bilaminar form described by Meckel and Macalister occurred once. Once the muscle almost formed a triangle, the truncated apex of which was formed by the radial end.

Cubito-carpeus.—This rare muscle arises from lower end of ulna, where it is in close contact with the pronator quadratus, forming, in fact, a detached portion of the latter; and it passes inwards to be inserted into the tuberosity of the scaphoid bone and base of the first metacarpal. It nearly corresponds to the *ulno-carpalis singularis anterior* of Gruber; but the latter is large at its ulnar attachment as the normal pronator, and is wholly inserted into the carpus.

Tensor ligamenti annularis (v. *orbicularis*) *dorsalis* (v. *posterior*).—Arising from the ulna behind the lesser sigmoid cavity, it is inserted into the posterior surface of the orbicular ligament of the radius. I found it as a distinct slip six times in thirty-four subjects. According to Macalister, its proportional frequency as a separate muscle is twenty-five per cent. of subjects examined; according to Gruber it has been found in seventy-four per cent. of fore-arms.

Tensor ligamenti annularis (v. *orbicularis*) *volaris* (v. *anterior*).—Arises from the coronoid process of the ulna, and is inserted into the anterior surface of the orbicular ligament of the radius. It is much less frequently seen than the other: it occurred in my cases twice in thirty-four subjects: according to Krause, the average frequency of its occurrence is seven per cent.

Supinator radii brevis accessorius.—Is a small slip from the brachialis anticus, going to the tubercle of the radius. I have seen two specimens.

Extensor carpi radialis longior; brevior.—These muscles I have found completely inseparable five times in thirty-four bodies. In one of the cases three tendons were given off—one to the second metacarpal bone, two to the third. In another instance a normal longior sent an accessory tendon to accompany that of brevior. Brevior had a double insertion in two of the fore-arms into second and third metacarpal bones.

Extensor communis digitorum.—Absence of the little finger tendon occurred in three of the subjects already referred to. Doubling of one or more of the tendons occurred in a large proportion of cases, but I made no note of the exact number.

Extensor minimi digiti.—This was completely absent in one instance. In two other cases there was a double tendon: in one of these the two slips were inserted together; in the other the second tendon went to the metacarpal bone of the ring finger. In one case the muscle was double, the second part forming the *extensor minimi digiti accessorius* (Krause).

Extensor brevis digitorum manus.—A rudimentary muscle, which is found in various forms of development on the back of the hand. The proportion of cases in which it occurs is, according to Krause, from three to seven per cent. It arises most frequently from the posterior annular ligament (Krause); sometimes from the end of the radius (Albinus, Humphry); from the bases of one or more of the metacarpal

bones (Wood, Macalister, &c.). I have seen but one specimen; it arose from the bases of the second and third metacarpal bones, and took some fibres from the adjacent part of the posterior annular ligament, and gave off two tendons which went to the index and middle digits—each joining with the corresponding tendon of the long extensor.

Extensor ossis metacarpi pollicis.—The tendinous end of this muscle presents very frequent variations. I have seen the tendon double; the second slip going in one case to the trapezium; in two instances to the abductor pollicis. A triple tendon occurred once: one had the normal attachment, the other two slips went to the trapezium, and to outer edge of abductor pollicis respectively. A quintuple tendon existed in one case: two of the slips went to the normal insertion, two to the trapezium, and one to become fused with the extensor primi internodii pollicis.

Extensor primi internodii pollicis.—This muscle was completely absent in one case; and in two others sent an accessory tendinous slip to the extensor secundi.

Of the muscles of the thenar eminence few notable variations were observed.

Abductor pollicis brevis alter; abductor pollicis internus.—Of this accessory bundle of muscular fibres—arising with the normal abductor and on its inner side—I have seen two examples.

Adductor pollicis.—In a large number of cases (of which, indeed, I kept no accurate record) the radial artery divided the muscle into two parts, as has been specially described by Bischoff, who has given the two divisions the names of *adductor pollicis obliquus*, and *adductor pollicis transversus* respectively.

Abductor minimi digiti.—This muscle I have found arising by two completely separate heads; one from the pisiform bone, the second from the anterior annular ligament.

Lumbricales.—The first was absent twice in thirty-four subjects. Both first and second were absent in another.

Psoas parvus.—A remarkable specimen of this muscle was met with last session. It had the usual origin; but the insertion was into the side of the cartilage between third and fourth lumbar vertebrae.

Iliacus minor; ilio-capsularis.—Analogous to the subscapularis minor in upper extremity. Arises from anterior inferior spine and ilio-femoral ligament, and is inserted, a little above the iliacus tendon, into the spiral line.

Tensor vaginae femoris.—In one case the origin of the muscle was three-quarters of an inch distant from the anterior superior spine of the ilium. The only other variation I have observed is the great difference in the length of its fibres in different subjects.

Sartorius.—I once found inserted into the inside of the capsule of the knee-joint.

Adductor minimus (Henle); *adductor quartus* (Diemerbrock).—This muscle is merely the upper and outer part of adductor magnus; I consider it worthy of separate mention because I have found it quite a

distinct muscle in the vast majority of cases I have examined. This has also been the experience of Professor Macalister.

Gluteus quartus; invertor femoris; scansorius.—This muscle is formed by a differentiated portion of the anterior part of the glutaeus minimus. When present its origin reaches as high as the anterior superior spine of the ilium. I have found it very distinct in three cases.

Gemellus superior.—This muscle I have found frequently absent. The inferior muscle I have never missed.

Quadratus femoris was found completely absent in two instances. One of these has been already published.

Biceps flexor cruris.—A third head to this muscle from the upper part of the linea aspera I have once seen. Absence of the short head was noted in two instances.

Gastrocnemius.—A third head of this muscle from the popliteal surface of the femur I have twice seen (*gastrocnemius tertius*, Krause). Accessory fibres of outer head arising from the external lateral ligament of the knee-joint I have found present in five instances.

Popliteus.—I have once found an accessory slip to this muscle arising above the normal popliteus from the external condyle of the femur.

Tensor capsuli tibio-tarsalis.—A very well developed specimen of this muscle I have once met with, arising from the outer surface of the tibia for the lower third, below and outside the tibialis anticus, and going to be inserted into the anterior annular ligament of the ankle-joint.

Peroneus quartus (Otto); *sextus* (Macalister); *p. accessorius.*—Of this muscle I have found one well-developed specimen (already published). It arose from the lower part of outer surface of fibula, where its fibres were found continuous with the lower part of the peroneus brevis. The insertion was into the outer surface of the os calcis, just behind the peroneal tubercle.

Peroneo-tibialis.—Arises from inner side of fibula just below the head, and is inserted into the oblique line of the tibia. Krause says it is present in eighteen per cent. of the subjects examined, and considers it analogous to the ulnar head of pronator radii teres. I have found it four times in forty-nine subjects in which it was specially looked for.

Pronator pedis; peroneo-calcaneus internus.—Arises from the fibula beneath and outside the origin of the flexor longus pollicis, and is inserted into the inside of the os calcis. It was considered by Meckel to be the analogue of the pronator quadratus in the upper extremity. I have seen but one example. The insertion was into the sustentaculum tali.

Besides the anomalies enumerated in the preceding pages, I have in my possession scattered notes of a considerable number, still unclassified, chiefly of the muscles of the lower extremity, which time has not permitted me to tabulate, but of which I shall take the earliest opportunity that time may afford to publish a complete list.

LXIV.—Preliminary Note on the Plane Representation of Certain Problems in the Dynamics of a Rigid Body. By Robert S. Ball, LL.D., F.R.S.

[Read, April 11, 1881.]

The present Paper applies to the case where the rigid body has freedom of the third order, and while the body remains in or near to its original position. Three co-ordinates will then specify any position which the body can attain. Two independent co-ordinates will specify the screw about which the body is twisting. The screws in the system can be most conveniently designated by three homogeneous co-ordinates of which only the ratios are concerned. The representation of a screw is therefore analogous to the representation of a point in a plane by trilinear co-ordinates. The object of this Paper is to develop this analogy. The reader is presumed to be acquainted with the elements of the *Theory of Screws*.

Let θ_1, θ_2, θ_3, be the co-ordinates of a screw θ, referred for convenience to the three principal screws of the *three-system*, which defines the freedom of the body (see *Theory of Screws*, p. 116). We can also denote the position of a point in a plane by the three co-ordinates θ_1, θ_2, θ_3, and hence we are led to the result that

To each screw of a three-system corresponds one point in the plane.

The converse of this is also *generally* true. It would be universally true but for one conic, and four points thereon, of a very remarkable character. To each of these points corresponds a whole plane of screws in the three-system, while the remaining points on the conic have no screws corresponding to them.

Two screws determine a cylindroid, and the co-ordinates of any third screw on the cylindroid are linear functions of the co-ordinates of the two given screws; and hence

To each cylindroid of screws belonging to the three-system corresponds a straight line in the plane.

It is well known that any two cylindroids of a three-system have one common screw. This theorem becomes sufficiently obvious when the cylindroids are represented by right lines, the common screw of course corresponding to their intersection.

If p_α, p_β, p_γ, be the pitches of the three principal screws of the system (*Theory of Screws*, p. 121), then the pitch p_θ of any other screw θ is given by the equation

$$p_\alpha \theta_1^2 + p_\beta \theta_2^2 + p_\gamma \theta_3^2 - p_\theta (\theta_1^2 + \theta_2^2 + \theta_3^2) = 0.$$

If we regard p_θ as given, then this equation corresponds to a conic section in the plane. To each pitch p_θ will correspond a different

conic. All the conics will form a family of the type $S + kS' = 0$, and they intersect in the same four points. These points are defined by the equations

$$p_\alpha \theta_1^2 + p_\beta \theta_2^2 + p_\gamma \theta_3^2 = 0,$$

$$\theta_1^2 + \theta_2^2 + \theta_3^2 = 0.$$

The first of these equations denotes the conic which corresponds to the screws of zero pitch. The second of the equations denotes the locus of the screws of infinite pitch. It is the exceptional conic just referred to. The four points common to their conics are of indeterminate pitch; they are indeed the exceptional points, and of course they are imaginary.

It has been shown (*Theory of Screws*, p. 121) that the locus of the screws of pitch p_θ in the three-system is the quadric

$$(p_\alpha - p_\theta)x^2 + (p_\beta - p_\theta)y^2 + (p_\gamma - p_\theta)z^2 + (p_\alpha - p_\theta)(p_\beta - p_\theta)(p_\gamma - p_\theta) = 0.$$

This is the real part of the locus, but the complete locus contains an imaginary portion also. This fact is at once exhibited by the plane representation. A straight line in the plane represents a cylindroid, *i. e.* a surface of the third degree. It hence followed that a conic in the plane should correspond to a surface of the sixth degree. We thus learn that the real locus of the screws of any given pitch must be *a surface of the sixth degree*, and that consequently the quadric with which we were already acquainted requires to be multiplied by a factor of the fourth degree.

It can be shown that this factor is the product of the four planes, produced by giving variety of sign to the coefficients in

$$\sqrt{p_\beta - p_\gamma}\,x + \sqrt{p_\gamma - p_\alpha}\,y + \sqrt{p_\alpha - p_\beta}\,z + \sqrt{p_\beta - p_\gamma}\sqrt{p_\gamma - p_\alpha}\sqrt{p_\alpha - p_\beta} = 0.$$

In general, if x, y, z be the co-ordinates of a point on a screw belonging to the system, and if θ_1, θ_2, θ_3 be its co-ordinates, then we have

$$x(\theta_2^2 + \theta_3^2) - y\,\theta_1\theta_2 - z\,\theta_1\theta_3 + (p_\beta - p_\gamma)\theta_2\theta_3 = 0,$$

$$y(\theta_3^2 + \theta_1^2) - z\,\theta_2\theta_3 - x\,\theta_2\theta_1 + (p_\gamma - p_\alpha)\theta_3\theta_1 = 0,$$

$$z(\theta_1^2 + \theta_2^2) - x\,\theta_3\theta_1 - y\,\theta_3\theta_2 + (p_\alpha - p_\beta)\theta_1\theta_2 = 0.$$

In the present case

$$\theta_1^2 : \theta_2^2 : \theta_3^2 :: p_\beta - p_\gamma : p_\gamma - p_\alpha : p_\alpha - p_\beta,$$

whence each of these equations reduces to

$$\sqrt{p_\beta - p_\gamma}\, x + \sqrt{p_\gamma - p_\alpha}\, y + \sqrt{p_\alpha - p_\beta}\, z + \sqrt{p_\beta - p_\gamma}\sqrt{p_\gamma - p_\alpha}\sqrt{p_\alpha - p_\beta} = 0.$$

Through each point in this plane a line can be drawn, whose direction cosines are proportional to

$$\sqrt{p_\beta - p_\gamma},\ \sqrt{p_\gamma - p_\alpha},\ \sqrt{p_\alpha - p_\beta},$$

It is remarkable that this line, besides lying in the plane, is also normal thereto, and with *any pitch whatever* this line will be a screw of the system.

Each of these planes of screws will correspond to one of the four remarkable points through which all the pitch conics pass. The plane representation of the screws in the three-system is thus seen to be more complete than the family of pitch quadrics which, until supplemented by the four imaginary planes, is not an adequate locus for all the screws of given pitch.

It will be convenient for our immediate purpose to designate the conics by the pitches to which they correspond. Thus we have the *zero-pitch conic*, the *infinite-pitch conic*, and their points of intersection we may speak of as the *fundamental points*.

Let θ and ϕ be two screws of the system, if they are reciprocal then (*Screws*, p. 35)

$$p_\alpha \theta_1 \phi_1 + p_\beta \theta_2 \phi_2 + p_\gamma \theta_3 \phi_3 = 0,$$

whence we deduce the result that

If two screws are reciprocal, then their corresponding points are conjugate with respect to the zero-pitch conic.

If the two screws were at right angles, then we would have the following relation between their co-ordinates :

$$\theta_1 \phi_1 + \theta_2 \phi_2 + \theta_3 \phi_3 = 0\,;$$

whence we find

If two screws are reciprocal, then their corresponding points are conjugate with respect to the infinite-pitch conic.

It will also be easy to show that

The angle between two screws is proportional to the logarithm of the anharmonic ratio in which the line joining their corresponding points is divided by the infinite-pitch conic.[1]

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[1] If we regard the infinite-pitch conic as the *absolute*, then the angle between two screws is nothing else than the "distance" in the non-Euclidian sense between their two corresponding points.

The vertices of the self-conjugate triangle that can be constructed with respect to the two conics correspond to screws mutually reciprocal and rectangular, whence

The principal screws of the three-system correspond to the vertices of the triangle which is self-conjugate with regard to the zero-pitch, and the infinite-pitch conic.

For the determination of a three-system nine data are required—for example, nine data will give the pitch quadric, and when that is known the rest of the system is determined. An equal number of data is required for the plane representation. Five of these may conveniently specify the zero-pitch conic, while the specification of the four fundamental points thereon will absorb the remainder.

The conic and four points being known, the self-conjugate triangle is determined; the equation of the conic referred to that triangle is therefore known, and thus the pitches p_α, p_β, p_γ of the three principal screws are determined. It remains to be shown how the pitch of the screw corresponding to any other point in the plane is to be ascertained.

It is not difficult to prove the following theorem:—

Measure off distances p_α, p_β, p_γ, p_θ on a straight line from an arbitrary point, then the anharmonic ratio of the four points thus obtained is equal to the anharmonic ratio which the point corresponding to θ subtends at the four fundamental points.

We are now able to construct the infinite-pitch, or any other pitch conic, from the primitive data, as the problem is merely to draw a conic through four points so that the anharmonic ratio subtended at those four points by a variable point shall be given.

Each screw of a three-system has one screw of the reciprocal system parallel to it, with a pitch of changed sign. If we take a plane representation and change the signs of all the pitches, then the new arrangement gives the screws of the reciprocal system parallel to all those of the old.

Two conics can be described through the four fundamental points to touch any given straight line; the two points of contact will indicate the two principal screws on the cylindroid corresponding to the straight line. The other pitch conics will cut the line in points which form an involution, each pair corresponding to the two screws of the same pitch on the cylindroid.

The polar of a point with regard to the zero-pitch conics corresponds to the cylindroid which is the locus of screws in the three-system reciprocal to a given screw.

On each cylindroid one screw ϕ reciprocal to a given screw θ can be found. It is only necessary to take the polar of θ with regard to the zero-pitch conic, and the point in which it intersects the line corresponding to the cylindroid gives the required screw.

By the aid of the plane representation we are enabled to solve many

problems in the dynamics of a rigid body which has freedom of the third order.

Let an impulsive wrench act upon a quiescent rigid body; it is required to determine the instantaneous screw about which the body will commence to twist.

It can be easily shown (*Screws*, p. 59) that the impulsive wrench, *wherever situated*, can always be adequately represented by an impulsive wrench on a screw of the three-system. The problem is therefore reduced to the determination of the point corresponding to the instantaneous screw, where that corresponding to the impulsive screw is known. In the special case where the freedom degrades to the rotation around a point, the problem now before us reduces to that solved in Poinsot's celebrated memoir.

We have first to draw the conic of which the equation is (*Screws*, p. 133)

$$u_1^2\,\theta_1^2 + u_2^2\,\theta_2^2 + u_3^2\,\theta_3^2 = 0.$$

This conic is of course imaginary, being in fact the locus of screws about which, if the body were twisting with the unit of twist velocity, the kinetic energy would nevertheless be zero. If two points θ, ϕ are conjugate with respect to this conic, then

$$u_1^2\,\theta_1\,\phi_1 + u_2^2\,\theta_2\,\phi_2 + u_3^2\,\theta_3\,\phi_3 = 0.$$

The screws corresponding to θ and ϕ are then what we have called *conjugate screws of inertia.*

This conic is referred to a self-conjugate triangle, the vertices of which are three conjugate screws of inertia. It is possible to find one self-conjugate triangle to the zero-pitch conic, and to the conic of inertia just considered. The vertices of this triangle are of especial interest. Each pair of them correspond to a pair of screws which are reciprocal, as well as being conjugate screws of inertia. They are therefore what we have designated as the *principal screws of inertia* (*Screws*, chapter VI.). They degenerate to the principal axes of the body when the freedom degenerates to the special case of the rotation around a fixed point.

When referred to this self-conjugate triangle, the relation between the impulsive point and the corresponding instantaneous point can be expressed with great simplicity. Thus the impulsive point ϕ, whose co-ordinates are

$$\theta_1\,u_1^2 \div p_\alpha;\quad \theta_2\,u_2^2 \div p_\beta;\quad \theta_3\,u_3^2 \div p_\gamma,$$

corresponds to the instantaneous point whose co-ordinates are θ_1, θ_2, θ_3. The geometrical construction is extremely simple when derived from the theorem thus stated.

If ϕ denote an impulsive screw, and θ denote the corresponding instantaneous screw, then the polar of ϕ with regard to the zero-pitch

conic is the same straight line as the polar of θ with regard to the inertia conic.

If H be the virtual coefficient of two screws θ and η, then

$$H^2(\theta_1^2 + \theta_2^2 + \theta_3^2) = (p_\alpha\theta_1\eta_1 + p_\beta\theta_2\eta_2 + p_\gamma\theta_3\eta_3)^2.$$

It follows that the locus of the points which have a given virtual coefficient with a given point is a conic [2] touching the conic of infinite pitch at two points. If ψ be the screw whose polar with regard to the infinite-pitch conic is identical with the polar of η with regard to the zero-pitch conic, then all the screws θ which make a given virtual coefficient with η are equally inclined to ψ. It hence follows that all the screws of a three-system which have a given virtual coefficient with a given screw are parallel to the generators of a right circular cone. All the screws reciprocal to η form a cylindroid, and ψ is the one screw of the system which is parallel to the nodal line of the cylindroid. The virtual coefficient of ψ and η is greater than that of η with any other screw.

If θ be a screw about which, when the body is twisting with a given twist velocity it has a given kinetic energy, then we must have

$$u_1^2\theta_1^2 + u_2^2\theta_2^2 + u_3^2\theta_3^2 - h^2(\theta_1^2 + \theta_2^2 + \theta_3^2) = 0,$$

where h^2 is a constant proportional to the energy. It follows that the locus of θ must be a conic constantly passing through the four points of intersection of

$$u_1^2\theta_1^2 + u_2^2\theta_2^2 + u_3^2\theta_3^2 = 0,$$
$$\theta_1^2 + \theta_2^2 + \theta_3^2 = 0.$$

The four points in which these two conics intersect correspond to the screws about which the body can twist with indefinite kinetic energy. These four points A, B, C, D being known, the kinetic energy appropriate to every point P can be readily ascertained. It is only necessary to measure the anharmonic ratio subtended by P, at A, B, C, D, and to set off distances u_1^2, u_2^2, u_3^2, h^2 on a straight line, so that the anharmonic ratio of the four points shall be equal to that subtended by P. This will determine h^2, which is proportional to the kinetic energy of the unit twist velocity about the screw corresponding to P.

A quiescent rigid body of mass M receives an impulsive wrench of given intensity on a given screw η; determine the locus of the screw θ belonging to the three-system, such that if the body be constrained to twist about θ, it shall acquire a given kinetic energy.

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[2] The non-Euclidian geometer will regard all such conics as "circles."

It follows at once (*Theory of Screws*, p. 136) that we must have

$$H(u_1^2\theta_1^2 + u_2^2\theta_2^2 + u_3^2\theta_3^2) = (p_\alpha\theta_1\eta_1 + p_\beta\theta_2\eta_2 + p_\gamma\theta_3\eta_3)^2,$$

where H is proportional to the kinetic energy. The required locus is therefore a conic having double contact with the inertia conic.

It is easy to prove from this that H will be a maximum if

$$u_1^2\theta_1 : p_\alpha\eta_1 = u_2^2\theta_2 : p_\beta\eta_2 = u_3^2\theta_3 : p_\gamma\eta_3;$$

whence we have Euler's well-known theorem that if the body be allowed to select the screw about which it will twist, the kinetic energy acquired will be larger than when the body is constrained to a screw other than that which it naturally chooses.

A somewhat curious result arises when we seek the interpretation of a tangent to the infinite pitch conic. This tangent must, like any other straight line, correspond to a cylindroid; and since it is the polar of the point of contact, it follows that every screw on the cylindroid must be at right angles to the direction corresponding to the point of contact. The co-ordinates of the point of contact must therefore be proportional to the direction cosines of the nodal line of the cylindroid.

If the body be in equilibrium under the action of a conservative system of forces, then there is a conic (analogous to the conic of inertia) which denotes the locus of screws about which the body can be displaced to a neighbouring position, so that even as far as the second order of small quantities no energy is consumed. The vertices of the common self conjugate triangle of this conic and the conic of inertia correspond to the harmonic screws about which, if the body be once displaced, it will continue for ever to oscillate.

The further development of the subject, on which this Paper is a preliminary note, must form the basis of a future and more extensive memoir.

LXV.—On Homographic Screw Systems. By Robert S. Ball, LL.D., F.R.S.

[Read, May 9th, 1881.]

I have lately ascertained that several of the most important parts of the *Theory of Screws* can be embraced in a more general theory. I propose in the present Paper to sketch this general theory. It will be found to have points of connexion with the modern higher geometry; in particular the theory of Homographic Screws is specially connected with the general theory of correspondence. I believe it will be of some interest to show how these abstract geometrical theories may be illustrated by dynamics. The intimate alliance which exists between the higher branches of rigid dynamics and the higher branches of modern geometry is perfectly natural. This will, I hope, be sufficiently illustrated in the present Paper. Among the more recondite theorems in rigid dynamics is that of the existence of a number of principal screws of inertia equal to the number of degrees of freedom which the body enjoys. Yet we shall show in this Paper that this is an instantaneous consequence of the purely geometrical theory of homographic screws.

We commence with the most general case in which the screws may be regarded as existing anywhere in space. I may remind the reader that a *screw* in the present sense of the word denotes a right line of specified situation and direction with which the linear magnitude termed the *pitch* is associated.

Given one screw α, it is easy to conceive that another screw β corresponding thereto shall be also determined. We may, for example, suppose that the co-ordinates of β (see *Theory of Screws*, p. 33) shall be given functions of those of α, or we may imagine a geometrical construction by the aid of fixed lines or curves by which, when an α is given, the corresponding β shall be forthwith known: again, we may imagine a connexion involving dynamical conceptions such as that, when α is the seat of an impulsive wrench, β is the instantaneous screw about which the body begins to twist.

As α moves about, so will the corresponding screw β: we thus have two *corresponding screw systems* generated. Regarding the connexion between the two systems from a purely analytical point of view, the co-ordinates of α and β will be connected by certain equations. It will not generally happen that a single screw β corresponds to a single screw α, and that conversely a single screw α corresponds to a single screw β; but *when this does happen the two systems of screws are said to be homographic.*

A screw α in the first system has one corresponding screw β in the second system; so also to β in the second system corresponds one screw α' in the first system. It will generally be impossible for α and

α' to coincide, but cases may arise in which they do coincide, and these will be discussed further on.

From the fundamental property of two homographic screw systems it follows that the co-ordinates of β must be expressed by six equations of the type—

$$\beta_1 = f_1(\alpha_1, \ldots \alpha_6)$$
$$\text{\&c., \&c.,}$$
$$\beta_6 = f_6(\alpha_1, \ldots \alpha_6).$$

If these six equations be solved for $\alpha_1 \ldots \alpha_6$ we must have—

$$\alpha_1 = F_1(\beta_1, \ldots \beta_6)$$
$$\text{\&c., \&c.,}$$
$$\alpha_6 = F_6(\beta_1, \ldots \beta_6).$$

It can be easily shown, that if $\alpha_1, \alpha_2 \ldots \alpha_6$ are to have unique values, then these equations must be linear; whence we have the following important result:—

In two homographic screw systems the co-ordinates of a screw in one system are linear functions with constant coefficients of the co-ordinates of the corresponding screw in the other system.

If we denote the constant coefficients by the notation (11) (22), &c., then we have the following system of equations:—

$$\beta_1 = (11)\alpha_1 + (12)\alpha_2 + (13)\alpha_3 + (14)\alpha_4 + (15)\alpha_5 + (16)\alpha_6,$$
$$\beta_2 = (21)\alpha_1 + (22)\alpha_2 + (23)\alpha_3 + (24)\alpha_4 + (25)\alpha_5 + (26)\alpha_6,$$
$$\text{\&c.,}$$
$$\beta_6 = (61)\alpha_1 + (62)\alpha_2 + (63)\alpha_3 + (64)\alpha_4 + (65)\alpha_5 + (66)\alpha_6.$$

It is now easy to show that there are six screws which coincide with their corresponding screws; for if $\beta_1 = \rho\alpha_1$, $\beta_2 = \rho\alpha_2$, &c., we obtain an equation of the sixth degree for the determination of ρ. We therefore have the following result:—

In two homographic screw systems six screws can be found, each of which regarded as a screw in either system coincides with its correspondent in the other system.

In two homographic rows of points we have the anharmonic ratio of any four points equal to that of their correspondents. In the case of two homographic screw systems we have a set of eight screws in one of the systems specially related to the corresponding eight screws in the other system.

We first remark that, given seven pairs of corresponding screws in the two systems, then the screw corresponding to any other

given screw is determined. For from the six equations just written by substitution of known values of $\alpha_1 \ldots \alpha_6$ and $\beta_1 \ldots \beta_6$, we can deduce six equations between (11), (12), &c. As, however, the co-ordinates are homogeneous and their ratios are alone involved, we can only use the ratios of the equations so that each pair of screws gives five relations between the 36 quantities (11), (12), &c. The seven pairs thus give 35 relations which suffice to determine linearly the ratios of the coefficients. The screw β corresponding to any other screw α is completely determined; we have therefore proved that—

When seven corresponding pairs of screws are given, the two homographic screw systems are completely determined.

A perfectly general way of conceiving two homographic screw systems may be thus stated:—Decompose a wrench of given intensity on a screw α into wrenches on six arbitrary screws. Multiply the intensity of each of the six component wrenches by an arbitrary constant; construct the wrench on the screw β which is the resultant of the six components thus modified; then as α moves into every position in space, and has every fluctuation in pitch, so will β trace out the homographic screw system.

It is easily seen that in this statement we might have spoken of twist velocities instead of wrenches.

The seven pairs of screws of which the two systems are defined cannot be always chosen arbitrarily. If, for example, three of the screws were co-cylindroidal, then the three corresponding screws must also be co-cylindroidal, and can only be chosen arbitrarily subject to this imperative restriction. More generally we shall now prove that if any $n + 1$ screws belong to an n-system (*Screws*, p. 38), then the $n + 1$ corresponding screws will also belong to an n-system. If $n + 1$ screws belong to an n-system it will always be possible to determine the intensities of certain wrenches on the $n + 1$ screws which when compounded together will equilibrate. The conditions that this shall be possible are easily expressed. Take, for example, $n = 3$, and suppose that the four screws $\alpha, \beta, \gamma, \delta$ are such that suitable wrenches on them, or twist velocities about them, neutralize. It is then obvious (see *Screws*, ch. V.) that each of the determinants must vanish which is formed by taking four columns from the expression—

$$\begin{vmatrix} \alpha_1, & \alpha_2, & \alpha_3, & \alpha_4, & \alpha_5, & \alpha_6, \\ \beta_1, & \beta_2, & \beta_3, & \beta_4, & \beta_5, & \beta_6, \\ \gamma_1, & \gamma_2, & \gamma_3, & \gamma_4, & \gamma_5, & \gamma_6, \\ \delta_1, & \delta_2, & \delta_3, & \delta_4, & \delta_5, & \delta_6 ; \end{vmatrix}$$

but it is easy to see that these determinants will equally vanish for the corresponding screws in the homographic system; for if we take for

reference the six common screws of the two systems, then we have at once for the co-ordinates of the screw corresponding to α—

$$(11)\,\alpha_1, \quad (22)\,\alpha_2, \quad (33)\,\alpha_3, \quad (44)\,\alpha_4, \quad (55)\,\alpha_5, \quad (66)\,\alpha_6.$$

When these substitutions are made in the determinants it is obvious that they still vanish; we hence have the important result that

The screws corresponding homographically to the screws of an n-system form another n-system.

Thus to the screws on a cylindroid will correspond the screws on a cylindroid. It is, however, important to notice that two reciprocal screws have not in general two reciprocal screws for their correspondents. We thus see that while two reciprocal screw systems of the n^{th} and $(6 - n^{th})$ orders respectively have as correspondents systems of the same orders, yet that their connexion as reciprocals is divorced by the homographic transformation.

Reciprocity is not therefore an invariantive attribute of screws or screw systems. There are, however, certain functions of eight screws analogous to anharmonic ratios which are invariants. These functions are of considerable interest, and they are not without physical significance.

We have already (*Screws*, p. 163) discussed the important function of six screws which is called the *Sexiant*. This function is most concisely written as the determinant $(\alpha_1\ \beta_2\ \gamma_3\ \delta_4\ \epsilon_5\ \zeta_6)$ where α, β, γ, δ, ϵ, ζ, are the screws. In Sylvester's language we may speak of the six screws as being in *involution* when their sexiant vanishes. Under these circumstances six wrenches on the six screws can equilibrate; the six screws all belong to a 5-system, and they possess one common reciprocal. In the case of eight screws we may use a very concise notation; thus $\overline{12}$ will denote the sexiant of the six screws obtained by *leaving out* screws 1 and 2. It will now be easy to show that functions of the following form are invariants:—

$$\frac{\overline{12}\ .\ \overline{34}}{\overline{13}\ .\ \overline{24}}.$$

It is in the first place obvious that as the co-ordinates of each screw enter to the same degree in the numerator and the denominator, no embarrassment can arise from the arbitrary common factor with which the six co-ordinates of each screw may be affected. In the second place it is plain that if we replace each of the co-ordinates by those of the corresponding screw, the function will still remain unaltered, as all the factors (11), (22), &c., will divide out. We thus see that the function just written will be absolutely unaltered when each screw is changed into its corresponding screw.

By the aid of these invariant functions it is easy, when seven pairs of screws are given, to construct the screw corresponding to any given eighth screw. We may solve this problem in various ways. One of the simplest will be to write the five invariants

$$\frac{\overline{12}\,.\,\overline{38}}{\overline{13}\,.\,\overline{28}},\quad \frac{\overline{13}\,.\,\overline{48}}{\overline{14}\,.\,\overline{38}},\quad \frac{\overline{14}\,.\,\overline{58}}{\overline{15}\,.\,\overline{48}},\quad \frac{\overline{15}\,.\,\overline{68}}{\overline{16}\,.\,\overline{58}},\quad \frac{\overline{16}\,.\,\overline{78}}{\overline{17}\,.\,\overline{68}}.$$

These can be all computed from the given eight screws of one system; hence we have five linear equations to determine the ratios of the coefficients of the required eighth screw of the other system.

It would seem that of all the invariants of eight screws, five alone can be independent. These five invariants are attributes of the eight-screw system, in the same way that the anharmonic ratio is an attribute of four collinear points. The curious inquirer may be tempted to speculate on the analogy between a group of eight screws which satisfy one or more of the conditions

$$\overline{12}\,.\,\overline{38} + \overline{13}\,.\,\overline{28} = 0,$$

and a row of four points, whereof two cut the other pair harmonically.

The invariants are also very easily deduced by considerations of a mechanical nature. It is not hard to conceive that to a dyname on one screw corresponds a dyname on the corresponding screw, and that the ratio of the intensities of the two dynames is to be independent of their intensities. We may take a particular case to illustrate the argument :—Suppose a free rigid body to be at rest. If that body be acted upon by an impulsive system of forces, those forces will constitute a wrench on a certain screw α. In consequence of these forces the body will commence to move, and its instantaneous motion cannot be different from a twist velocity about some other screw β. To one screw α will correspond one screw β, and (since the body is perfectly free) to one screw β will correspond one screw α. It follows, from the definition of homography, that as α moves over every screw in space, β will trace out an homographic system. . . . From the laws of motion it will follow, that if F be the intensity of the impulsive wrench, and if V be the twist velocity which that wrench evokes, then $F \div V$ will be independent of F and V, though, of course, it is not independent of the actual position of α and β.

It is known (*Screws*, p. 171) that when seven wrenches equilibrate (or when seven twist velocities neutralize), the intensity of the wrench (or the twist velocity) on any one screw must be proportional to the sexiant of the six non-corresponding screws.

Let F_{18}, F_{28}, &c., F_{78} be the intensities of seven impulsive wrenches on the screws 1, 2, . . . 7, which equilibrate, then we must have

$$\frac{F_{18}}{\overline{18}} = \frac{F_{28}}{\overline{28}} = \&c. = \frac{F_{78}}{\overline{78}}.$$

Similarly, by omitting the first screw, we can have seven impulsive wrenches which equilibrate, where

$$\frac{F_{12}}{\overline{12}} = \frac{F_{13}}{\overline{13}} = \frac{F_{14}}{\overline{14}} = \&c. = \frac{F_{18}}{\overline{18}};$$

hence we have

$$\frac{\overline{12} \,.\, \overline{38}}{\overline{13} \,.\, \overline{28}} = \frac{F_{12} \,.\, F_{38}}{F_{13} \,.\, F_{28}}.$$

Let the instantaneous twist velocity corresponding to F_{18} be denoted by V_{18}, then, as when seven wrenches equilibrate, the seven corresponding twist velocities must also equilibrate, we must have in the corresponding system,

$$\frac{\overline{12} \,.\, \overline{38}}{\overline{13} \,.\, \overline{28}} = \frac{V_{12} \, V_{38}}{V_{13} \, V_{28}}.$$

But we must have the twist velocity proportional to the impulsive intensity; hence, from the second pair of screws we have

$$F_{28} : V_{28} :: F_{12} : V_{12},$$

and from the third pair,

$$F_{38} : V_{38} :: F_{13} : V_{13};$$

hence we deduce

$$\frac{V_{12} \,.\, V_{38}}{V_{13} \;\; V_{28}} = \frac{F_{12} \,.\, F_{38}}{F_{13} \;\; F_{28}},$$

and, consequently, the function of the eight impulsive screws,

$$\frac{\overline{12} \,.\, \overline{38}}{\overline{13} \,.\, \overline{28}},$$

must be identical with the same function of the instantaneous screws.

It should, however, be remarked, that the impulsive and instantaneous screws do not exhibit the most general type of two homographic systems. A more special type of homography, and one of very great interest, characterizes the two sets of screws referred to. As

this special type is also of importance for other kinetic problems, it will be desirable to examine into its general character.

If the general linear transformation, which changes each screw α into its correspondent θ, be specialized by the restriction that the co-ordinates of θ are given by the equations

$$\theta_1 = \frac{1}{p_1}\frac{dU}{da_1},$$

$$\theta_2 = \frac{1}{p_2}\frac{dU}{da_2},$$

&c.,

$$\theta_6 = \frac{1}{p_6}\frac{dU}{da_6},$$

where U is any homogeneous function of the second order in $a_1, \ldots a_6$, and where $p_1, \ldots p_6$ are the pitches of the screws of reference, then the two systems are related by the special type of homography to which I have referred.

The fundamental property of the two special homographic systems is thus stated :—

Let α and β be any two screws, and let θ and ϕ be their correspondents, then, when α is reciprocal to ϕ, β will be reciprocal to θ.

We may, without loss of generality, assume that the screws of reference are co-reciprocal, and in this case the condition that β and θ shall be co-reciprocal is

$$p_1\beta_1\theta_1 + p_2\beta_2\theta_2 - \ldots + p_6\beta_6\theta_6 = 0\ ;$$

but by substituting for $\theta_1 \ldots \theta_6$, this condition reduces to

$$\beta_1\frac{dU}{da} + \ldots + \beta_6\frac{dU}{da} = 0.$$

Similarly, the condition that α and ϕ shall be reciprocal is

$$\alpha_1\frac{dU}{d\beta_1} + \ldots + \alpha_6\frac{dU}{d\beta_6} = 0.$$

It is obvious that as U is an homogeneous function of the second degree, these two conditions are identical, and the required property has been proved.

It is easily shown that by suitable choice of the screws of reference the function U may, in various ways, be reduced to the sum of six square terms. We now proceed to show that this reduction is pos-

sible in one way, while still retaining six co-reciprocals for the screws of reference.

The pitch p_α of the screw α is given by the equation (*Screws*, p. 35)

$$p_\alpha = p_1 \alpha_1^2 + \ldots + p_6 \alpha_6^2 :$$

the six screws of reference being co-reciprocals, the function p_α must retain the same form after the transformation of the axes. The discriminant of the function

$$U + \lambda p_\alpha$$

equated to zero will give six values of λ; these values of λ will determine the coefficients of U in the required form. I do not, however, enter further into the discussion of this question, which belongs to the general theory of linear transformations.

The transformation having been effected, an important result is immediately deduced. Let the transformed equation be denoted by

$$(11)\ \alpha_1^2 + \ldots + (66)\ \alpha_6^2 = 0,$$

then we have

$$\beta_1 = \frac{1}{p_1}(11)\ \alpha_1,$$

$$\ldots\ldots$$

$$\beta_6 = \frac{1}{p_6}(66)\ \alpha_6;$$

whence it appears that the six screws of reference are the common screws of the two systems. We thus find that in this special case of homography

The six common screws of the two systems are co-reciprocal.

It is proved (*Screws*, p. 48) that the correspondence between impulsive screws and instantaneous screws is of the type here referred to. The six common screws of the two systems are therefore what we have called the *principal screws of inertia*, and they are co-reciprocal.

The special circumstances under which a screw α has the same correspondent, whichever of the two systems α be regarded as belonging to, demands a few words. If we take the six common screws of the two systems as the screws of reference, then the condition stated can only be fulfilled when the relation has the form

$$\beta_1 = \pm\ \alpha_1,$$

$$\ldots$$

$$\beta_6 = \pm\ \alpha_6.$$

For example, if

$$+\alpha_1, \quad +\alpha_2, \quad +\alpha_3, \quad +\alpha_4, \quad +\alpha_5, \quad +\alpha_6$$

be the co-ordinates of one screw, and if

$$-\alpha_1, \quad +\alpha_2, \quad +\alpha_3, \quad +\alpha_4, \quad +\alpha_5, \quad +\alpha_6$$

be the corresponding screw, then the two systems will fulfil the required condition. We thus have a kind of screw involution analogous to what is known as the relation of involution between the rows of points on the same line.

If we add the further restriction, that the six common screws are co-reciprocal, the homography is then of a very special type. The pitch of each screw,

$$p_1\alpha_1^2 + \ldots + p_6\alpha_6^2,$$

is equal to that of the corresponding screw, and the virtual coefficient,

$$p_1\alpha_1\beta_1 + \ldots + p_6\alpha_6\beta_6,$$

of two screws is equal to that of the two corresponding screws. In the particular case, when the virtual coefficient is zero, we see that if two screws be reciprocal, so are also the two corresponding screws. The angle ϕ between two screws is, however, not preserved; for, as shown elsewhere,[1]

$$\cos\phi = \Sigma\alpha_1\beta_1 + \Sigma\,(\alpha_1\beta_2 + \alpha_2\beta_1)\,h_{12},$$

when h_{12} is the cosine of the angle between the two screws of reference, 1 and 2. Cos ϕ is thus altered when the signs of α_1 and β_1 are changed. It is also evident that the perpendicular distance d between the two screws is altered, for the virtual coefficient is

$$(p_\alpha + p_\beta)\cos\phi - d\sin\phi.$$

We have seen that this function, as well as p_α and p_β, remain unaltered; hence, since ϕ is changed, we must also have d changed. I have not hitherto seen any instance in which this highly specialized form of homography is presented in a physical question.

There is a form of correspondence, very frequently of importance, which must now be considered in detail. For the sake of illustration, suppose a body which is at rest, and which has two degrees of freedom, be struck by any impulsive system of forces. These forces may constitute a wrench of any pitch, and anywhere, yet the movement

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[1] *Transactions* of this Academy, vol. xxv. p. 306.

which the body can accept is limited, and the body can, indeed, only twist about one of the singly infinite number of screws which constitute a cylindroid. To any screw in space will correspond one screw on the cylindroid. But will it be correct to say, that to one screw on the cylindroid corresponds one screw in space? The fact is, that there are a quadruply infinite number of screws, an impulsive wrench on any one of which will make the body choose the same screw on the cylindroid for its instantaneous movement. The relation of this quadruply infinite group is well known in the *Theory of Screws*. It is shown (*Screws*, p. 110) that, given a screw α on the cylindroid, there is one screw θ on the cylindroid, an impulsive wrench on which will make the body commence to twist about α. It is further shown that any screw whatever which fulfils the single condition of being reciprocal to a single specified screw on the cylindroid possesses the same property. The screws thus form a 5-system. The correspondence at present before us is therefore to be thus stated—

To one screw in space corresponds one screw on the cylindroid, and to one screw on the cylindroid corresponds a 5-system in space.

We may look at the matter in a more general manner. Consider an m-system (A) of screws, and an n-system (B) $(m > n)$. If we make $m = 6$ and $n = 2$, this system includes the system we have been just discussing. To one screw in A will correspond one screw in B, but to one screw in B will correspond, not a single screw in A, but an $(m + 1 - n)$ system of screws.

If $m = n$, we find that one screw of one system corresponds to one screw of the other system. Thus, if $m = n = 2$, we have a pair of cylindroids, and one screw on one cylindroid corresponds to one screw on the other. A set of four screws on a cylindroid, being all parallel to a plane, we may speak of the anharmonic ratio of four co-cylindroidal screws, and we obtain the result that it is equal to the anharmonic ratio of the four corresponding screws (*Screws*, p. 106). If $m = 3$, and $n = 2$, we see that to each screw on the cylindroid will correspond a whole cylindroid of screws belonging to the 3-system. For example, if a body have freedom of the second order, a whole cylindroid full of screws can always be chosen from any 3-system, an impulsive wrench on any one of which will make the body commence to twist about the given screw.

The property of the screws common to the two homographic systems will of course require some modification when we are only considering an m-system and an n-system. Let us take the case of a 3-system on the one hand, and a 6-system, or all the screws in space, on the other hand. To each screw α of the 3-system A must correspond, a 4-system, B in space. The screws of this 4-system are in such profusion, that a whole cone full of them can be drawn through every point in space. Amid this multitude it is most interesting to note that one screw β can be found, which, besides belonging to B, belongs also to A. Take any two screws reciprocal to B, and any

three screws reciprocal to A, then the single screw β, which is reciprocal to the five screws thus found, belongs to both A and B. We thus see that to each screw α of A, one corresponding screw in the same system can be determined. The result just arrived at can be similarly shown generally, and thus we find that when every screw in space corresponds to a screw of an n-system, then each screw of the n-system will correspond to a $(7-n)$ system, and among the screws of this system one can always be found which lies on the original n-system.

As a mechanical illustration of this result we may refer to the theorem, that if a rigid body has freedom of the n^{th} order, then, no matter what be the system of forces which act upon it, we may always combine the resultant wrench with certain reactions of the constraints, so as to produce a wrench *on a screw of the n-system* which defines the freedom of the body, and this wrench will be dynamically equivalent to the given system of forces.

It is easy to state the matter analytically, and for convenience we shall take a 3-system, though it will be obvious that the process is quite general.

Of the six screws of reference, let three screws be chosen on the 3-system, then the co-ordinates of any screw on that system will be $\alpha_1, \alpha_2, \alpha_3$, the other three co-ordinates being equal to zero. The co-ordinates of the corresponding screw β must be indeterminate, for any screw of a 4-system will correspond to β. This provision is secured by $\beta_4, \beta_5, \beta_6$ remaining quite arbitrary, while we have for $\beta_1, \beta_2, \beta_3$ the definite values,

$$\beta_1 = (11)\,\alpha_1 + (12)\,\alpha_2 + (13)\,\alpha_3,$$

$$\beta_2 = (21)\,\alpha_1 + (22)\,\alpha_2 + (23)\,\alpha_3,$$

$$\beta_3 = (31)\,\alpha_1 + (32)\,\alpha_2 + (33)\,\alpha_3.$$

If we take $\beta_4, \beta_5, \beta_6$, all zero, then the values of $\beta_1, \beta_2, \beta_3$, just written, give the co-ordinates of the special screw belonging to the 3-system, which is among those which correspond to α.

As α moves on the 3-system, so will the other screw of that system which corresponds thereto. There will, however, be three cases in which the two screws coincide; these are found at once by making

$$\beta_1 = \rho\alpha_1; \quad \beta_2 = \rho\alpha_2; \quad \beta_3 = \rho\alpha_3,$$

whence we obtain a cubic for ρ.

It is thus seen that generally n screws can be found on an n-system, so that each screw shall coincide with its correspondent. As a dynamical illustration we may give the important theorem, that when a rigid body has n degrees of freedom, then n screws can always be found, about any of which the body will commence to twist when it

receives an impulsive wrench on the same screw. These screws are the principal screws of inertia.

We have already seen the anharmonic equality between four screws on a cylindroid, and the four corresponding screws; we have also shown a sort of *quasi* anharmonic equality between any eight screws in space and their correspondents. More generally, any $n + 2$ screws of an n-system are connected with their $n + 2$ correspondents, by relations which are analogous to anharmonic properties. The invariants are not generally so simple as in the 8-screw case, but we may state them, at all events, for the case of $n = 3$.

Five screws belonging to a 3-system, and their five correspondents are so related, that, given nine of them, the tenth is immediately determined; for this two data are required, that being the number required to specify a screw already known to belong to a given 3-system.

We may, as before, denote by $\overline{12}$ the condition that the screws 3, 4, 5 shall be co-cylindroidal. This, indeed, requires no less than four distinct conditions, yet, as pointed out (*Screws*, p. 44), functions can be found whose evanescence will supply all that is necessary. Nor need this cause any surprise, when it is remembered that the evanescence of the sine of an angle between two lines contains the two conditions necessary that the direction cosines are identical. The function

$$\frac{\overline{12} \,.\, \overline{34}}{\overline{13} \,.\, \overline{24}}$$

can then be shown to be an invariant which retains its value unaltered when we pass from one set of five screws in a 3-system to the corresponding set in the other system. When two invariants are known, the required screw is determined.

LXVI. REPORT ON THE CLEARING OF PEATY WATERS. PART I. By GERRARD A. KINAHAN.

[Read, May 9th, 1881.]

Introduction.

IN the spring of 1880 Professor Hartley, F.R.S.E., suggested that I should make certain experiments on peaty waters, as he had observed that some peaty streams become rapidly decolourized, while others flow for considerable distances without undergoing any alteration. Besides furnishing me with some observations and the results of some experiments he had made, he desired me to direct my attention specially to the action of clays, and the more commonly occurring lime salts, in order to determine whether they or natural oxidation of the peaty matter played the more important part in the decolourizing of peaty streams.

Professor Hartley had remarked that along the course of the River Affaric, in Invernesshire, flowing from Loch Affaric through Loch Benevian to join the River Glass, a distance of about six miles over a hard rocky bed (quartzite, micaceous schist, and basalt), no alteration in the colour of the water was detected, though for three weeks while the observations were carried on no rain fell, and there was abundance of sunshine, the stream being frequently lashed into foam along its course.

He found that peaty waters can be partially purified by an admixture of hard water of about 26° of hardness on Clarke's scale. Also that when a mixture of hard water and soft peaty water was softened by adding lime water, the calcic carbonate carried down much peaty colouring matter, the purification being more effectual than in the last case.

He ascertained also that about two to three grains of sulphate of alumina were sufficient to decolourize ten gallons of darkish peaty water, the dark brown matter settling down in about twenty-four hours. From this it might be anticipated, as was actually proved by experiment, that certain clays, when mixed with the water, would have a similar effect.

Professor Hartley also remarks that Mr. J. Y. Buchanan, late of the scientific staff of the Challenger, has found that the water at the bottom of some of the Highland Lochs is colourless, while the surface water is peaty; the material at the bottom being blue or white clay. One particular instance of this occurs at Loch Ness, in places where the water is from 50 to 110 fathoms deep.

In this Report I propose to give, first, the field notes made on streams in the Ovoca river basin, with the results of some of my laboratory experiments suggested by these observations, to which are added some notes on the inferences to be drawn from both.

The experiments in the laboratory were carried on, more or less simultaneously with the observations in the field on peaty streams; notes on the latter being supplemented by experiments in the former.

Observations on Peaty Streams.

These observations were made almost solely on the waters of the Ovoca river basin, and principally on those of its tributaries, the Ow and the Avonbeg.

The rocks occurring in this basin are granite, clay slate more or less metamorphosed, with a few thin bands of limestone, and patches of eruptive rocks. The superficial coverings to these are the *drifts*, whether glacial, which may have been transported from some distance, and contain foreign substances; or meteoric, due to the disintegration of the underlying rocks; gravels, occurring principally in the valleys; and peat, found on the mountain slopes and in some places in the valleys.

From this it would appear that in this river basin for the most part there is an absence of rocks yielding carbonate of lime, or lime salts; the sources from which these might be derived being the few fragments of limestone in the glacial drifts, the marls, which are rare, the few bands of limestone scattered through the slates, and the eruptive ashes containing crystallized calcite.

Thus the waters of this district may be classified generally as very soft waters, with a few small local exceptions.

Along the main streams (Ow and Avonbeg), the depth of tint of the colouring varied greatly, from local causes such as the state of a tributary; but in a few cases the variations are, as yet, inexplicable. The most satisfactory results were not, therefore, obtained from these larger streams, but from their tributaries; and of these, one of the most interesting and instructive is the Ballynagappoge brook.

It had been noticed that, as a rule, in any peaty stream the waters were more darkly coloured at the head waters than anywhere lower down; therefore, when examining the variations in the amount of colouring along the course of a stream, the method usually adopted was as follows:—Starting from the head with a sample of the water, we proceeded down stream, till some alteration in the state of the stream occurred; this might be due to the junction with another stream, or an alteration in the river bed, such as a marked change in the rate of fall, or the occurrence of clay or gravel. Here a second sample of water was taken, and compared with the first, by placing both side by side in two similar tumblers on a white surface, the differences in depth of tint being then noted; proceeding down stream with these two samples, the next comparison was made where the next remarkable change took place; if the depth in tint here was very different from the last, the second sample was discarded, and this third carried down for comparison at the next point of observation, the first, or the sample

taken at the head waters, being always retained for comparison along the course, but more particularly with a sample taken where the stream joined the main river. In the small brooks or tributaries the waters cleared going down stream, but in the larger rivers very irregular changes often occur, their waters being affected by the character of each of the tributaries.

The thickness of the stratum examined in the tumblers was about 4½ inches; which was found sufficient for all purposes in the field, as a very slight alteration in the colour could be detected; but for more detailed and accurate purposes in the laboratory a thicker stratum is desirable.

In these peaty waters there appear to be two distinct colouring matters, one producing a brown of various degrees of intensity, the other an olive-green;[1] the mixture of the two colouring matters in proper proportion produces a brown-green, but as a general rule the former obscures the latter.

It may be here pointed out that no correct estimate of the alterations in the depth of tint of peaty colouring matter that take place along the course of a stream can be formed by only looking at the waters in the stream; because the thickness of the stratum of water looked at, *i. e.* the depth of the river, may change, and the bottom of the river may be variously coloured: some marked changes, however, may be detected by observing the difference in the colour of the foam that forms at the different small falls along a stream.

By the method as sketched out above, the principal tributaries belonging to the Ow and Avonbeg were carefully examined from their head waters to their junction with the main rivers, and their effect on each main river, if any, was noted. This was done by comparing a sample taken from the main river just above where it was joined by the tributary, with one taken below the first fall or rapid that occurred after their junction, where their waters would be well mixed.

The examination of the streams was repeated during different stages of flood, and different seasons of the year. It appears that, as a rule, the streams are more peaty in summer than in winter; and that after continuous dry weather the peaty matter is much reduced. During cold frosty weather, or when there is snow on the mountains, very little peaty colouring is found in the streams.

The Ballynagappoge brook, which drains the N.W. slope of Croaghanmoira and discharges into the Ow, affords, as previously pointed out, much instruction. When examined during the summer it was found at its head waters to be of a deep brown, but when it joined the Ow after a flow of about 1½ miles with a fall of about 500 feet it had become quite clear and limpid; all its feeders are peaty, except a small one that enters it below Rosahane-bridge after the principal decolourization has taken place. This brook therefore may be described in detail.

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[1] I find that Dr. Tidy states (*Chem. Soc. Jour.*, 1880, p. 293), that the *brown* colour is due to old peat, the *olive-green* to more recent peaty matter.

The head waters above Ballynagappoge bridge are deeply tinted with peaty colouring matter; the bed of the stream here is marshy, with a slaty rock appearing in places; below the bridge there is more rock, less marsh, while a little gravelly clay appears in places; some distance down, the stream is joined by another of about equal size and about equally coloured, but which has been flowing along a somewhat gravelly bed. Just before its junction with this stream the brook had not so deep a colour as it had at Ballynagappoge bridge. The united streams wash against the foot of a blue clayey cliff, from which a considerable quantity of clay is evidently removed during flood time; below this cliff the bed of the stream is composed of a bare slaty rock with very little gravel resting upon it; the depth of tint of the water gradually but very slowly becomes reduced along this part of the course. Here the stream flows rapidly and forms a succession of little falls; this rocky bed, with its rapid fall, giving place at about 500 yards above Rosahane bridge to a clayey and gravelly bed with a reduced rate of fall. Between the point where this change occurs and the bridge the peaty colouring in the stream, which was considerable, is reduced to a mere trace, while a short distance below the bridge it is completely removed. Along this portion of the stream, just above the bridge, where the fall is slight, there are several marshy places from which iron-stained waters flow into the brook; this staining is due to the waters containing some ferrous salt (probably ferrous carbonate) in solution, which, on contact with the air, is decomposed or oxidized, depositing ferric hydrate or ochre. On the stones and in the pools about this part of the stream there is a dark brownish deposit; some of this was collected with the surrounding water, which had a slight peaty tinge. On standing, this water gave a yellow ferruginous precipitate, the water becoming most beautifully clear and limpid. It was found that the sediment collected consisted of a little sand and clay, with iron, alumina, magnesia, a little manganese and organic matter.

These iron springs appear to be the agents that, to a great extent, clear the waters; for although in all probability, clays in suspension, or the very small quantity of soluble matter that is dissolved out of them, will carry down a large amount of peaty colouring matter, yet, except when present in very large proportion, they seem incapable of decolourizing the waters completely.

The ferrous salts in these waters are probably derived from the reduction, by decomposing organic matter, of the ferric salts contained in the underlying rocks and clays.

The decolourizing of the waters of this brook is evidently not due to the direct oxidation of the peaty matter; nor is the diminution of the depth of tint due to dilution. In this stream it so happens that, where the fall is greatest, there the clearing of the water is least.

During December, 1880, it was remarked that the main rivers contained very little peaty colouring matter in them; about this time there had been slight frosts in the valleys, but upon the mountains there was

snow. On visiting the Ballynagappoge brook it was found that the waters were quite colourless and clear. Up to the head waters above Ballynagappoge-bridge no peaty colouring matter could be detected; the snow did not reach as low as this bridge.

It should be mentioned that though in cold weather little peaty colouring matter is in the streams, yet in the bog-holes (turf-holes) the water is quite brown.

The Caraway stick brook may be next described, as it is an example of a different class. Along its course very little diminution of the peaty tint occurs, though there is every facility for oxidation; the brook descending a height of about 1200 feet in a flow of less than two miles.

This brook flows from Kelly's lough, a small sheet of peaty water about eight acres in extent, on the S.E. slope of Lugnaquilla at an elevation of about 1700 feet above the sea. On the S.W. of the lough there is a granite cliff; the brook leaves the lough at the N.E. corner, flowing through the remains of an ancient glacial moraine in a north-westerly direction, for over a mile, with a slight inclination, then for the rest of its course (about half a mile) it descends a height of 700 feet (calculated by aneroid) over a bed composed of granite and schist, by a succession of falls and rapids, the waters being lashed into foam down nearly all that part of its course. From a comparison of samples taken both above and below the falls, no difference could be detected in the depth of tint of the waters.

During one of our visits, after there had been no rain for three or four days, it was remarked that the waters were not nearly so deeply coloured as on a previous visit, when showers were falling on the mountains. On this occasion, before ascending, a sample of water was taken at the foot of the falls, then about a cubic yard of a sandy clay was put into the stream above the fall, rendering it very turbid; then taking a second sample of water just above the turbidity, we descended to where the first had been taken from, and here after the turbid water had been flowing for some little time a third sample was taken. On comparing the samples subsequently, after the turbidity in No. 3 had completely subsided, this sample was darkest, while there was no apparent difference in tint between Nos. 1 and 2.

Along the Avonbeg the changes that occur are irregular, although on the whole there is a diminution in the depth of tint as we descend to the "Meeting of the Waters." Here it is joined by the Avonmore, and in a sample from this latter river, taken here in May, 1880, a small quantity of lead (0·028 parts per 100,000) was detected.

The united Rivers Avonmore and Avonbeg form the Ovoca, which a short distance down receives the waters from the Ovoca mines; first on its east or left bank, from the mines of Tigroney, Cronebane, and Connary; these containing ferrous sulphate, and sulphate of alumina in comparatively large proportions, with smaller quantities of other salts, as sulphate of copper, and arsenic. Lower down the river, coming in from the west or right bank, is the drainage of the Bally-

murtagh and Ballygahan mines. In a sample of water taken at the tail of the Landers, a litre of water was found to contain 0·81 grammes ferrous sulphate, and 0·78 grammes sulphate of alumina (equivalent to 56·8 grains ferrous sulphate, and 54·7 grains sulphate of alumina, per gallon), besides small quantities of arsenic and sulphate of copper, &c.

A sample of water taken from the Ovoca river, below, or after it had received these mineral waters, was very peaty when collected, and slightly turbid, but on standing some time a brown precipitate settled, with a considerable reduction of the tint; on another occasion, when the river was not so deeply tinted, by allowing a sample to settle for a time, the peaty colouring was completely removed, and in the laboratory about five cc. of the Ballygahan water cleared 250 cc. of a very peaty water; a dark brown precipitate first settling down, then a yellowish precipitate of ochre.

All along the Ovoca river, from the mines to its mouth in Arklow harbour, there is a ferruginous ochre deposited in the pools and on the stones; this being probably due to the ferrous salts in the waters becoming oxidised, this precipitation being accompanied by a considerable reduction of the peaty colouring matter in the river. A sample of water taken from the river below the place where this mine drainage enters is always found to contain a very finely divided precipitate of ochre which shortly settles out.

Though the Ovoca river is usually peaty, particularly during flood, it was remarked that in frosty weather, and when there was snow on the mountains, the peaty colouring was much reduced, and often entirely removed; the same was noticeable after a long continued drought, the river running perfectly colourless above the mines.

Experiments with Peaty Waters.

These experiments, commenced in the spring of 1880, and carried on under the direction of Professor Hartley, F.R.S.E., in his laboratory at the Royal College of Science for Ireland, had for their object the determination of the agents that may effect the decolourisation of peaty waters, more especially of those that actually effect it in nature.

As clays occur in some form or other along the beds and banks of most streams, and as during floods they become suspended in the waters to a greater or less extent, some of the first experiments were made with such clays.

Specimens were obtained, principally from the County Wicklow, of disintegrating argillaceous rocks and clays; many of these, however, were subsequently rejected, as it was found that they contained organic matter sufficient to discolour the water and obscure their action on the peaty colouring matter in it.

In each experiment a measured quantity of water was shaken up with a weighed quantity of clay, then left to allow the substances in suspension to subside. When the water had cleared, a portion was decanted off and placed in a tall narrow cylinder; in some of the experiments

the cylinder used was 6 inches high, in others 18 inches; this vessel of the sample experimented on was compared, on a white surface, with a precisely similar vessel of the same water, which had been previously freed from peaty colouring matter by mixing with it a large enough quantity of clay. By so treating any peaty water it was found that the peaty colouring matter could be completely removed, provided only sufficient clay were added.

Specimen A.—This is a fine cream-coloured clay from the foot wall of the gossan (iron ore) of the Ballymurtagh North sulphur lode, of which it forms the "selvage." Scattered through it is a small quantity of fragments of iron pyrites and milk quartz; with water it yields a clear solution, having an acid reaction, and containing a small percentage of ferrous sulphate and sulphate of alumina.

Insoluble in hydrochloric acid,	92·51 per cent.
Ferric oxide,	2·35 per cent.
Alumina,	2·43 per cent.

It was found to be a most efficient decolouriser of peaty waters.

When added to peaty water, the greater portion settled down almost immediately, but the very fine particles remained in suspension for a considerable time; when these had subsided, if sufficient clay had been used, the water was very clear; the top layer of the sediment being brown, as if the colouring matter had been carried down in it.

If an insufficient quantity of this clay were added to the water, several different stages were to be noted.

A very small quantity of clay altered the colour from a brown to a brown-green, and on adding a little more clay the colour altered to an olive-green. When more clay was added, but not sufficient to clear the water, a peculiar turbidity or cloudiness formed, which remained persistent, and did not appear to decrease on filtering. When this turbidity was removed by adding more clay, the water was freed from peaty colouring matter.

With the specimen of peaty water used in these experiments it was found that working with 1000 cc. of water not very darkly coloured, 1 gramme of clay brought on the brown-green stage; 1·5 grammes of clay the olive-green; 2·5 grammes produced a persistent turbidity; and that 4 grammes removed the cloudiness and the peaty colouring.

In order to determine what the active ingredient in this clay might be, some of it was digested in hydrochloric acid; the insoluble portion after being well washed was found to have very little perceptible action on the peaty water.

A strong aqueous solution of the clay was prepared (10 grammes of clay to 300 cc. of distilled water); this solution with a small quantity of the suspended particles was found to be capable of freeing the water from peaty colouring. After filtering the clay solution, it was found that the filtrate possessed the same property.

From these two experiments it is evident that it was something dissolved out of the clay that acted on the peaty matter, and that the insoluble portion had very little to do with it.

As on examining the clay solution it was found that it contained ferrous sulphate, a solution of ferrous sulphate was prepared; and of this a few drops caused a peculiar turbidity to form, then a brown precipitate settled to the bottom, and the water was found to be free from peaty colouring matter.

Sulphuric acid, hydrochloric acid, and nitric acid were also found to precipitate the peaty colouring matter to some extent.

Specimen B.—A disintegrated light yellow red steatitic shale, occurring in a dyke-like mass in the townland of Ballykillageer:—

It yields with water a turbid yellowish liquid, which clears on standing, the suspended particles subsiding; the solution is neutral to test paper, and none of the clay appears to be dissolved in it.

Insoluble in hydrochloric acid,	78·28 per cent.
Ferric oxide,	8·12 ,,
Alumina,	7·96 ,,
Manganese,	trace.

This specimen also cleared peaty waters of their colouring matter, though not so well as the last. When sufficient clay was added to entirely clear the water (25 grammes in 1000 cc.), the top layer of the sediment, which was formed of the fine particles that had remained longest in suspension, was more deeply coloured than the rest.

When an insufficient quantity of clay was added to the peaty water, the changes were similar to those taking place with the last specimen, viz., an alteration of the brown colour to a deep olive-green; after which a cloudiness or turbidity appeared, but it disappeared when sufficient clay had been added.

On digesting about 5·5 grammes of this clay with water, filtering and evaporating the filtrate to dryness, only a very minute inorganic residue is left, showing that there is very little soluble matter in the clay.

Specimen H.—A bluish clay occurring in a cliff on the Ballynagappoge brook. During floods a considerable portion is washed into the stream, and it probably assists in the decolourising of the waters of this brook, as mentioned in the field notes, p. 450, *supra.*

Digested with hydrochloric acid, it gives—

Insoluble portion,	81·79 per cent.
Ferric oxide,	6·72 ,,
Alumina,	6·47 ,,

When mixed with peaty water it seems capable of removing the brown tint, but incapable of removing the greenish tinge; the water, however, remains slightly turbid.

When mixed with clear and colourless water it forms a very dirty turbid solution; after some time this clears considerably, but the liquid always retains a peculiar turbidity, which is very like the turbidity produced in a peaty water when an insufficiency of the clearing agent has been added. It was found that the turbidity could be removed by adding a small quantity of the next specimen to be described.

This blue clay seems to have been originally a red clay, very similar to that next mentioned (specimen *I*); its present condition being due to percolating peaty waters. This is inferred from the following observations:—1st. A similar blue clay overlies specimen *I*, as seen in the banks along the Mucklagh brook, the passage from one to the other being gradual; red stones and patches of red clay are seen occurring in this overlying clay. 2nd. The residues left by both specimens, after digesting in hydrochloric acid, are alike. 3rd. The percentage of insoluble matter in specimen *H* is greater than in specimen *I*, the more soluble portions, iron and alumina, having been probably removed by percolating waters.

Specimen I.—A brick red clay from one of the tributaries of the Mucklagh brook, where it occurs under a blue clay like the last specimen, a gradual passage from one to the other being distinctly visible. It yields an insoluble residue similar to the last, but the percentage of soluble matter is greater.

Insoluble in hydrochloric acid,	72·41 per cent.
Ferric oxide,	9·70 ,,
Alumina,	9·41 ,,

It yields with water a perfectly clear solution when the fine particles have subsided; which, however, is not for some considerable time.

This specimen acts as a very efficient decolouriser of peaty waters. When mixed with a peaty water the fine particles remaining in suspension give the liquid a brick-red colour; when they subside the peaty water is found to be quite decolourised, if sufficient (about 20 grammes to 1000 cc.) has been added.

With an insufficiency of clay the usual changes are observed.

Specimen K.—A whitish sandy clay, from the banks of the Caraywaystick brook, where it occurs in an ancient moraine above the falls; it was some of this specimen that was mixed with the waters of this brook, as mentioned in the field notes, p. 451, *supra*.

Insoluble in hydrochloric acid,	93·91 per cent.
Ferric oxide,	1·60 ,,
Alumina,	2·17 ,,

This specimen, even in large quantities, produces very little alteration in peaty water; when added, very little remains in suspension for any length of time.

With a colourless water it yields a clear solution.

Specimen N.—A growan, or disintegrating granite, from Aughavannagh, Co. Wicklow. This rock occurs extensively in this district, underlying the peat. Deep channels are cut in it by the streams, which are not as peaty as might be expected, considering that they drain extensive bogs. In this growan are large veins of massive quartz and feldspar, which more or less resist disintegration.

The growan appears composed of quartz, and feldspar (the latter passing into kaolin, or china clay), with black and white mica.

Insoluble in hydrochloric acid,	86·68 per cent.
Ferric oxide,	3·80 ,,
Alumina,	6·24 ,,

This specimen at first seems to have very little effect on peaty waters, but, after remaining in the water some time, a layer of less darkly-coloured water was observed next to the clay. By repeatedly shaking up the clay and water, at long intervals, a marked reduction of peaty tint was observed in the water.

Some of the feldspar, mentioned as occurring in large veins through this specimen, after being pulverised, was found to act very similarly; a reduction of peaty tint only taking place after some time, and after being repeatedly shaken up. This feldspar contains only a very small quantity of iron, is very hard, and little altered.

In both the above cases, the top of the sediment at the bottom of the peaty water, after standing some time, becomes coated with a brownish substance.

With respect to the ingredients of these clays that are the active agents in decolourising the peaty water, it was found by experiment that a pure quartzose sand, even when in very large quantities, had no perceptible effect on the colouring of the water.

Pure gelatinous silica had likewise no effect.

The portion of a clay that is insoluble in hydrochloric acid was found to have at first no action on peaty water; but after repeatedly shaking the two up together it was found that the depth of colour was slightly reduced.

It was also found that freshly precipitated aluminic hydrate, ferric hydrate, and manganese oxy-hydrate precipitated the colouring matter rapidly and efficiently; of these the alumina is by far the most active; next the iron, the manganese being considerably less efficient.

The dry oxides of these metals were not found to be nearly so rapid in their action; in the case of ferric oxide and manganese dioxide it was only after being shaken up repeatedly that any decrease in the tint could be noticed; when left at rest for a considerable time, the layer of water next the oxide became decolourised; this extended gradually upwards, the surface of the oxide being coated with a brownish substance. This clearing of the bottom layer, and its gradual extension upwards, was most marked when a little potassic bisulphate was

placed at the bottom of a vessel containing peaty water. There is a marked analogy between this layer of clear water at the bottom of the vessels, and that mentioned by Professor Hartley, as occurring at the bottom of some of the Scotch lakes.

Magnesia was not found to affect the peaty colouring; pure carbonate of lime has only a very slight effect on the peaty colouring; pounded up chalk and limestone were found to reduce the tint slightly.

A hard water has only a very slight effect on the peaty colouring; but, on precipitating the carbonate of lime in the mixed waters, either by boiling or by adding to it lime-water, a large quantity of the peaty colouring is removed.

Lime-water added to a peaty water precipitates the peaty colouring.

By mixing some fresh hydrate of alumina and water together, filtering the solution, and adding some of the filtered liquid to some peaty water, the colouring matter was precipitated. By similarly treating hydrates of iron and manganese no precipitation of peaty matter was obtained.

In the field it was remarked that during frost, or when there was considerable snow in the drainage area of the river, the waters did not run nearly so peaty as at ordinary times, and often ran quite colourless, and mountain streams which at other times were deeply tinted were under these circumstances perfectly clear. Therefore some peaty water was frozen in tall cylinders, and it was found that although the peaty colouring matter was not precipitated, yet the behaviour was interesting, as the colouring appeared to resist freezing.

In such water, when the freezing took place gradually from above downwards, a layer of deeply coloured peaty water collected at the bottom, but the water resulting from the thawing of the small cylinder of ice was quite free from peaty colouring. When the freezing took place from the sides, a central core of darkly coloured peaty water collected. When the solidification took place rapidly, the darkly-coloured peaty water appeared enclosed in small patches through the block of ice, as though squeezed out of the freezing water, and concentrated in these patches which did not seem to freeze.

On freezing a cylinder of peaty water gradually from above downwards, then taking out the block of ice, leaving the layer of deeply coloured water at the bottom of the cylinder, refilling with peaty water and again freezing, and repeating this several times, a very small quantity of brown sediment settled down to the bottom.

Boiling peaty water gently for some time does not precipitate the peaty colouring matter; before a boiling temperature is reached, bubbles of gas escape from the liquid.

The discolouration which results from boiling peat for some time with distilled water can be almost entirely removed by filtering; but by adding a little ammonia to the water before warming, a large quantity of colouring matter becomes dissolved, giving the water a very dark colour. This colour is removed neither by filtering nor by boiling the water for a considerable time.

Conclusions from the preceding observations.

From the preceding observations in the field and in the laboratory it may fairly be inferred that—

Peaty colouring matter seems not to be removed by direct oxidation; this appears specially from the Carawaystick brook, where exceptional facilities occur for oxidation, and no peaty tributaries enter along that portion of the stream where it is lashed into foam down a height of about 700 feet.

Oxidation may play a certain part in precipitating peaty colouring matter, in so far that a ferrous salt, on becoming oxidised, carries down with it the peaty colouring matter; this appears to be an important factor in the decolourising of peaty streams; waters that are charged with ferrous carbonate flowing into them have the iron precipitated, the peaty colouring going down with it.

Ferrous sulphate also acts as an efficient decolouriser, but its occurrence must be comparatively rare; however, in the Ovoca river it plays an important part, and it is the most active agent in the clay specimen *A*; in the other specimens experimented upon it is the combined oxides of iron and aluminum, with manganese to a less extent, that appear to be the active ingredients: what their action on the peaty colouring matter may be has not been determined, but in ordinary peaty water there seem to be at least two distinct colouring substances; the one gives to the water a brown tint, which is comparatively easily removed, the other, only to be remarked when the brown has disappeared, gives it a greenish hue, which it is difficult to get rid of.

The peaty colouring is precipitated to a greater or less extent by either hydrochloric, nitric or sulphuric acids, more especially the last; it has also been found, as far as the experiments have gone, that salts having acid reactions act similarly, and some organic acids to a less extent.

When these observations were commenced, it was not anticipated that frost or dry weather would have had much effect upon the peaty colouring of streams. Why such is the case seems somewhat difficult to explain, especially as the experiments in the laboratory seem to prove that the peaty colouring is not precipitated by freezing.

After a long continuance of dry weather the waters in the streams and rivers are derived not from surface drainage but from springs, *i. e.* underground drainage, where the waters have been stored in the pores of the rock, and slowly percolating through the joints and crevices; any peaty matter these waters might have contained after percolating the overlying peat would probably be precipitated by the clayey matter contained in the joints of the rock. At the same time, any little drainage there might be from the peat probably collects in the holes that are always to be found; here the colouring becomes deepened, partly by evaporation of the water, but principally by dissolving out colouring matter from the surrounding peat. This may account for the reduction of tint observed after long continued dry weather.

In frosty weather the case is similar; the surface of the bogs is frozen, preventing the percolation of waters, and the water supply is often derived from melting snows; in one case it was observed that though a quantity of peaty water had collected behind a snowdrift, yet the water flowing from the other side of the drift was quite colourless.

In wet weather the principal supply of water is derived from the surface and superficial accumulations; that which flows from bogs and peaty ground is more or less tinted, as rain falling on these lands displaces the water contained in the reservoirs of the bogs, *i.e.* the pores of the peat and the surface holes such as "bog-holes," "turf-holes," and mountain loughs: as these waters contain a large amount of dissolved peaty matter, they flow into the streams deeply tinted.

At the commencement of dry weather the reservoirs in connexion with the rivers, such as lakes and pools, contain peaty waters, and it is not until these have been altogether displaced by clear water from springs, &c., that the streams flowing therefrom run colourless. The larger, therefore, a river and its reservoirs are, the longer it takes to become perfectly colourless.

Of the Shannon above Limerick, after the late long continued drought (March and April, 1881), there having been very little rain, and no floods for weeks, Captain King writes—"we have had no floods for a long time, and the river is in its purest state, even its usual boggy appearance has taken flight."

LXVII. — Report on an Investigation of the Character and Chemical Constitution of the Fibre of the Flax Plant. By F. Hodges, Fellow Inst. C.F.C.S. (Berlin), Zürich. With Plates XIV. and XV.

[Read, May 9, 1881.]

Kirwan, so early as 1789, laid the results of some experiments which he had made with the alkaline substances used in bleaching, before the Members of the Royal Irish Academy, prefacing his Report with the statement "that, however well the Irish bleachers might excel in that art, when well provided with the instruments they employ, they were but little acquainted with the general agency of the instruments themselves and their respective powers, or even with the most advantageous and economical method of employing them;" and Kolb in his elaborate Report to the Members of the Industrial Society of Mulhausen, 79 years later (1868), gave it as his opinion that the art of bleaching was no further advanced, so far as chemistry is concerned, than at the time of the introduction of chlorine by Berthollet. With the statement of Kirwan, few who know anything of Irish bleachers even now will be inclined to disagree; but with that of Kolb it is somewhat different, as it cannot be forgotten that on many occasions, long and laborious investigations into the constitution of textile fabrics, and the nature of the various chemicals employed as bleaching agents, have been made by eminent chemists; and if practical men have failed to turn to advantage the results obtained from these investigations—which results have been published from time to time—the chemists who undertook the work should at least be acquitted of the charge of being idle in the interests of bleachers.

Kolb, in the Report above mentioned, published the results of many experiments, which, if they had been carried out with Irish flax, instead of with Russian yarn spun from dew retted flax, would not only have possessed scientific interest, but have been of practical value to the Irish bleacher. It has, therefore, been considered advisable to repeat part of his investigation, with Irish flax, as well as to endeavour if possible to add to the very scanty information which we have of the nature of the wax and other bodies which exist in flax. We owe to Sir Robert Kane the first attempt to direct scientific attention to the composition of the stem of the flax plant. In a Report drawn up by Professor Hodges, at the request of the chemical section of the British Association of Science, and communicated to the Meeting held in Belfast, the agricultural and technical history of the plant was fully discussed, and the results of an extensive series of investigations on its composition given. This Report was the first in which an analysis of the proximate composition of the stem was published, and

it was followed, at subsequent Meetings, by Reports, by the same chemist, on the gases evolved in the steeping process; on the composition of the steep-water; and on the composition of dressed flax. In this preliminary Report of a series of investigations on which I have been for some time engaged, I have endeavoured to extend our knowledge of the nature of some of the organic constituents of the plant, and also of the effect of certain agents on the fibre. Flax as sold to the spinner consists, as is well known, of long and fine filaments, separated from the stem of the plant usually in this country by a process called "retting," in which a decomposition of some of the cementing materials which hold together the structures of the plant is effected, so that the textile filaments can be completely detached from the non-elastic and worthless portion of the stem, by the mechanical means afterwards employed. The cells which serve technical purposes in the flax plant are those which exist in the bast tissue; these cells, of which the fundamental material is cellulose, are accompanied with various incrusting and intercellular matters, which easily undergo solution or decomposition by chemical means—sulphate of aniline, as suggested by Wiesner, affords a test of exceeding delicacy for these incrusting matters, by the production of a yellow colour. The bast cells, as shown by the microscope, consist of long thick-walled cells in which the lumen has almost entirely disappeared. Iodine and sulphuric acid render the bast cells blue, while sulphate of aniline on the unbleached fibre shows the presence of some adhering and incrusting matter, by the production of a vivid golden-yellow colour; in the perfectly purified and bleached fibre this re-agent usually causes no change of colour, unless some of the incrusting matters have not been removed. The short cells and vessels which are situated on the inner side of the bast bundles of the plant are not rendered blue by the action of iodine and sulphuric acid. A series of of longitudinal and transverse sections of the structures which compose the stem of the plant, made in the laboratory of Professor Hodges, and carefully delineated by Mr. Tuffen West, whose abilities in drawing microscopic objects is so well known, affords probably the most perfect representation of their histological character which has hitherto been made, and also serves to show the effect of re-agents and the arrangement and mode of union of the cells. The action of nitric acid as shown in Plate XIV., fig. 1, is instructive as exhibiting the spiral striation of the thickening layers; while that of sulphuric acid and iodine on the section of an isolated cell, as exhibited in Plate XV., fig. 1, displays the concentric layers. In Plate B, fig. 2, the position of the groups of the bast fibres in the stem of the plant is well shown: fig. 3 shows the cuticle with stoma and remains of chlorophyll. A more full description of these Plates will be given in a subsequent communication.

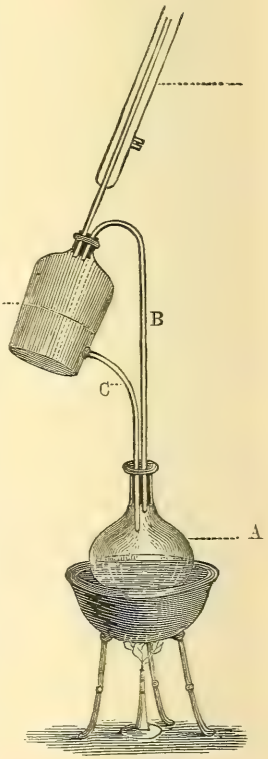
Chemical Examination.

The flax fibre used in this investigation was pure Irish milled flax, of medium quality.

Estimation of loss of weight on drying.

7·6805 grms. flax fibre after drying at 100° C. for 12 hours weighed 6·796 grms., loss of weight 0·8845 grms. = 11·5 per cent. 5·07625 grms. of yarn manufactured from the same flax, after drying 12 hours at 100° C., weighed 4·5800; loss of weight 0·49625 grms. = 9·7 per cent.

After the retting of the flax, the gummy matters which were originally, says Kolb, uniformly spread over the fibre, disappear, and are replaced by numerous brilliant scales of a resinous appearance, equally distributed in the substance of the fibre, and in a manner adhering by their roughness to the filaments. These scales have a light amber hue, and are deepened in colour by alkalies, in which they can be entirely dissolved. By the mechanical process of hackling, large quantities of scaly matters are removed from the fibre. This substance, the nature of which is so little known, has been very differently named by many chemists; Berthollet calls it yellow colouring matter; Kirwan considered it a resin, differing from the true resins by its insolubility in the essential oils; M. Rouget de Lisle thought that it was, in combination with two others, of the nature of gummy extractive matter; Grimshaw ascribed the colour of raw flax and cotton to the presence of iron. In pursuance of the course of investigation here undertaken, it was considered proper to begin by studying the character of the bodies extracted from the flax by ether and alcohol, which was done in the following manner:—In order to obtain a sufficient amount of the bodies soluble in ether, the extraction was effected on a large scale in an apparatus which will be seen, by the accompanying sketch, to consist of a 4-litre bottle, with a tubule at the bottom, fused in an inclined position for better running off, which held about 400 grms. flax each time. The tube B carries the ether vapour from the flask underneath into the extraction bottle, and thence into a cooler, where it is condensed. The tube C carries the ether charged with wax and colouring matters back into the flask. Though all the most approved plans proposed for ether and alcohol extraction were tried, none were found so effective as the one here described, which during three days extracted 1·5 kg. flax with 4 litres of ether. The ethereal solution gradually turned light-green, and finally rather dark. On the cooling of the concentrated solution, a substance separated in white mammillary or flocculent masses. The hot extract was



filtered and the ether distilled off. There remained behind a greenish mass consisting of wax and essential oil. The latter was distilled off, and, on being submitted to fractional distillation, it proved to be largely contaminated with alcohol from the ether. The oil proper, which had a yellow colour, boiled at 85–100° C., and had an extremely disagreeable acrid smell. Though very large quantities of flax were at different times extracted, the quantity of this essential oil which was obtained was too small to prepare a product of constant boiling point for analysis. Though other workers on flax have mentioned the existence of this oil, none of them have ever given its boiling point, nor indeed separated it from the other matters extracted with it. I hope, before the conclusion of this investigation, to succeed in obtaining a sufficient quantity to enable me to fully study its character. In order to purify the white-coloured substance, it was dissolved repeatedly in hot alcohol, filtered while hot through a hot water funnel, and precipitated by cooling. By this means it could be separated almost entirely from chlorophyll, of which there was a very large quantity, and from a brown resinous substance very difficult to dissolve, which deposited at the bottom of the vessel, and solidified on cooling; of this substance there were traces to be seen even after ten repetitions of this operation. By long continued washing with cold ether, and drawing off with a pipette, at last a loose mass was obtained, showing a very slight greenish-yellow colour. Dried over sulphuric acid, it melted at 78° C., already at 74° C. it was partially liquefied. The solidification took place at 72° C. This proves that it was still a mixture of several substances, an opinion which is confirmed by the results of saponification with melting potash.

Two combustions of the wax (melted and dried at 100° C.) yielded—

I.—*Substance employed*, 0·2090 grm.

CO_2	0·6060
H_2O	0·2483

Found C, 79·07 per cent., H, 13·19 per cent.

II.—*Substance employed*, 0·1685 grm.

CO_2	0·4940
H_2O	0·2042

Found C, 79·95 per cent., H, 13·46 per cent.

The following possible ethers correspond to the percentages quoted beside them:—

		C.	H.	
Cerotic ceryl ether, $C_{27}H_{53}OO(C_{27}H_{55})$,	requires	82·24	13·71	per cent.
Palmitic melissyl ether, $C_{16}H_{31}OO(C_{30}H_{61})$,	,,	81·65	13·60	,,
Palmitic ceryl ether, $C_{16}H_{31}OO(C_{27}H_{55})$,	,,	81·39	13·51	,,
Palmitic ceryl ether, $C_{16}H_{31}OO(C_{16}H_{33})$,	,,	80·00	13·33	,,

From which it can be seen that the last formula very nearly agrees with the results of the combustion.

Saponification.

Though this part of my work is far from being completed, owing to numerous difficulties which have presented themselves, it will, I believe, yield rich results. The method by which I proceeded was as follows:—Pure potash was fused in a silver dish, and about 6 grammes dry wax put in, in small portions. A soapy smell arose at once. The brown sticky soap was from time to time taken off with an iron spatula and put in water. After the operation was finished, the whole was put in a large quantity of water, and boiled for some time, till all was dissolved into a milky liquid. Then barium chloride was added, and the liquid filtered off the insoluble baryta salt, and the equally insoluble wax alcohols, which were washed with water. The mixture was boiled with ordinary alcohol to dissolve the new wax alcohol, filtered while hot, and the operation repeated four times. The last traces of adhering wax alcohol were removed by washing the baryta salt on the funnel with hot spirits of wine. The united alcoholic filtrates were concentrated to a small volume, by which the wax alcohol separated out and was removed by filtration. Purified once more by dissolving in absolute alcohol and dried, it melted at 82° C., a temperature which is open to correction, and requires further investigation, to ascertain the perfect freedom of the body from other substances, but which, if found to be correct, agrees with the fusing point of ceryl alcohol, which Brodie gives at 79° C., and Duffy at 81° C.

Preparation and Examination of the Fatty Acid obtained as a Barium Salt.

The barium salt was boiled for some time with strong acetic acid, and the fatty acid, which separated, filtered off. It was a brown substance melting at about 82° C. It dissolved in hot alcohol, with yellow colour, leaving behind a blackish-brown glutinous mass which solidified on cooling. This proves the existence of, at least, two fatty acids in the wax, or it leads to the supposition that it is a mixture of several ethers. Only that part which dissolved in alcohol was further examined. After repeated purifications with hot alcohol, it was obtained as a lead salt, by precipitation with lead acetate from a hot alcoholic solution. In this it was found that even the portion soluble in alcohol must be a mixture of several fatty acids. Along with a white flocculent lead precipitate, there was formed a brown precipitate, also containing lead, melting at a boiling heat, and adhering to the sides of the glass vessel. The two precipitates could be separated by prolonged boiling and pouring off of the liquid. The flocculent lead salt, which was present in large quantity, was filtered off and washed with hot alcohol. Dried at 80° C., and decomposed by hot acetic acid,

it formed a waxy acid floating on the liquid, melting at 82° C. The quantity of this was not sufficient for a combustion, and I had to content myself with preparing the ethyl ether, by dissolving the acid in absolute alcohol, and passing through dry hydrochloric acid gas. The ether was precipitated on the cooling of the liquid in microscopically small needles, melting at 60–61° C., and solidifying in a crystalline form. Both the melting point of the free acid and that of the ethyl ether agree very nearly with the data for cerotylic acid. Cerotylic or cerotic acid, F. p. 81–82° C.; Cerotic ethyl ether, F. p. 60·3° (Brodie). If the elementary analyses agree, these data will make it probable that the acid is cerotylic acid.

Extraction with Ether and Alcohol.

20·8555 grammes dried flax were extracted with absolute ether for twenty-four hours, and weighed 20·0455 grammes: loss of weight 0·810 gramme = 3·88 per cent.

The extract freed from ether (white wax and green oil) weighed 0·8057 gramme, corresponding to 3·86 per cent. loss of weight. The 20·0455 grammes, after extracting with absolute alcohol for twenty-four hours, weighed 19·9455 grammes: loss = 0·1000 = 0·45 per cent. The alcoholic extract was of a deep brown colour, and after evaporation of the alcohol evolved a smell similar to over-ripe stawberries. Kolb, in his experiments, found 4·8 per cent. capable of being extracted with ether and alcohol; but he carried his investigation no further than to give it as his opinion that the matters extracted were composed of two bodies of different densities—a wax, and an odorous essence, the former probably complex, all of which had been long ago shown to be the case by Dr. Hodges, and is now confirmed by the above experiments.

Extraction with Caustic Soda Solution.

18·734 grammes flax, previously extracted with ether and alcohol, and dried at 100° C.–112° C. for twelve hours, were boiled with caustic soda liquor, till no further loss of weight took place; remaining weight 13·406 grammes: loss 5·328 grammes = 28·4 per cent.

Preparation of Pectic Acid.

A large quantity of flax previously extracted with ether and alcohol was boiled for a short time, say one-half to one hour, with caustic soda solution, and a little sodium carbonate. The decanted liquor was decolourised as much as possible by animal charcoal, and filtered. The liquor was faintly brown. This liquor, according to Fremy, should contain pectic acid, as it is his idea that if either the ferment, to which he gave the name of pectase, or the free alkalies, or their carbonates, be allowed to act on a substance containing the organic body pectine, they can, the former at a temperature of 30° C.,

and the latter even in the cold, transform it, in the first instance, into pectosates and pectates, and finally, if their action be continued, into the remaining bodies of the series. The liquor gave, with an excess of hydrochloric acid, a brown gelatinous precipitate, which was washed on the filter with hot water for some time. During the washing the precipitate swelled a good deal, and much passed through the filter, so that gelatinous flakes deposited in the filtrate. In spite of washing, the precipitate still contained alkali (in 0·21925 grm. of dried precipitate 0·0025 grm. ashes). It dissolved in liquor ammonia with brown colour; the solution yielded a gelatinous precipitate with barium chloride. After drying, it resembled in appearance a woody brown mass, soluble in ammonium oxalate, but insoluble in absolute alcohol and ether.[1] On boiling with water it swelled up, and was gradually dissolved as presumably metapectic acid; which was shown by its reducing Fehling's solution, by turning brown with alkalies, and by yielding a gelatinous precipitate with silver nitrate. The solution gave an acid reaction with litmus. All the reactions here given agree with Fremy's statements about metapectic acid.

Extraction with Lime and Preparation of Calcium Metapectate.

A large quantity of raw flax was boiled for twelve hours with excess of milk of lime. The solution was filtered and freed from free calcium hydrate by a current of carbonic dioxide at a boiling heat. The filtered brown solution of calcium metapectate was concentrated and decolourised by animal charcoal. By evaporation in a platinum dish, a substance was obtained, at first gummy, then hardening, and still rather yellowish and rather hygroscopic. Two samples were powdered and dried for twelve hours at 100–110° C.

1·0632 grms. yielded on ignition ·2477 grms. CaO = 23·22 per cent.
·504 ,, ,, ,, ·119 ,, CaO = 23·61 ,,

The solution of calcium metapectate gave no precipitate with hydrochloric acid, nor with barium chloride and neutral lead acetate, but only with basic lead acetate. The precipitate was soluble in an excess of the precipitant. In order to ascertain whether Kolb was correct in his idea of the non-existence of a resinous saponification, many experiments were undertaken; and though they, like the rest of my work, are far from being completed, a few of them are here enumerated, the results of which, so far as they have gone, tend to confirm Kolb's conclusions.

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[1] This is interesting, inasmuch as Messrs. Cross and Bevan, while working on a substance prepared in a somewhat similar manner from the jute fibre, state that they found it to be soluble in alcohol, and, therefore, not pectic acid; which is rather remarkable, as Schunk found a pectic compound in the cotton fibre: and Dr. Hodges and M. Kolb, in their researches on flax, describe the presence of pectic compounds.

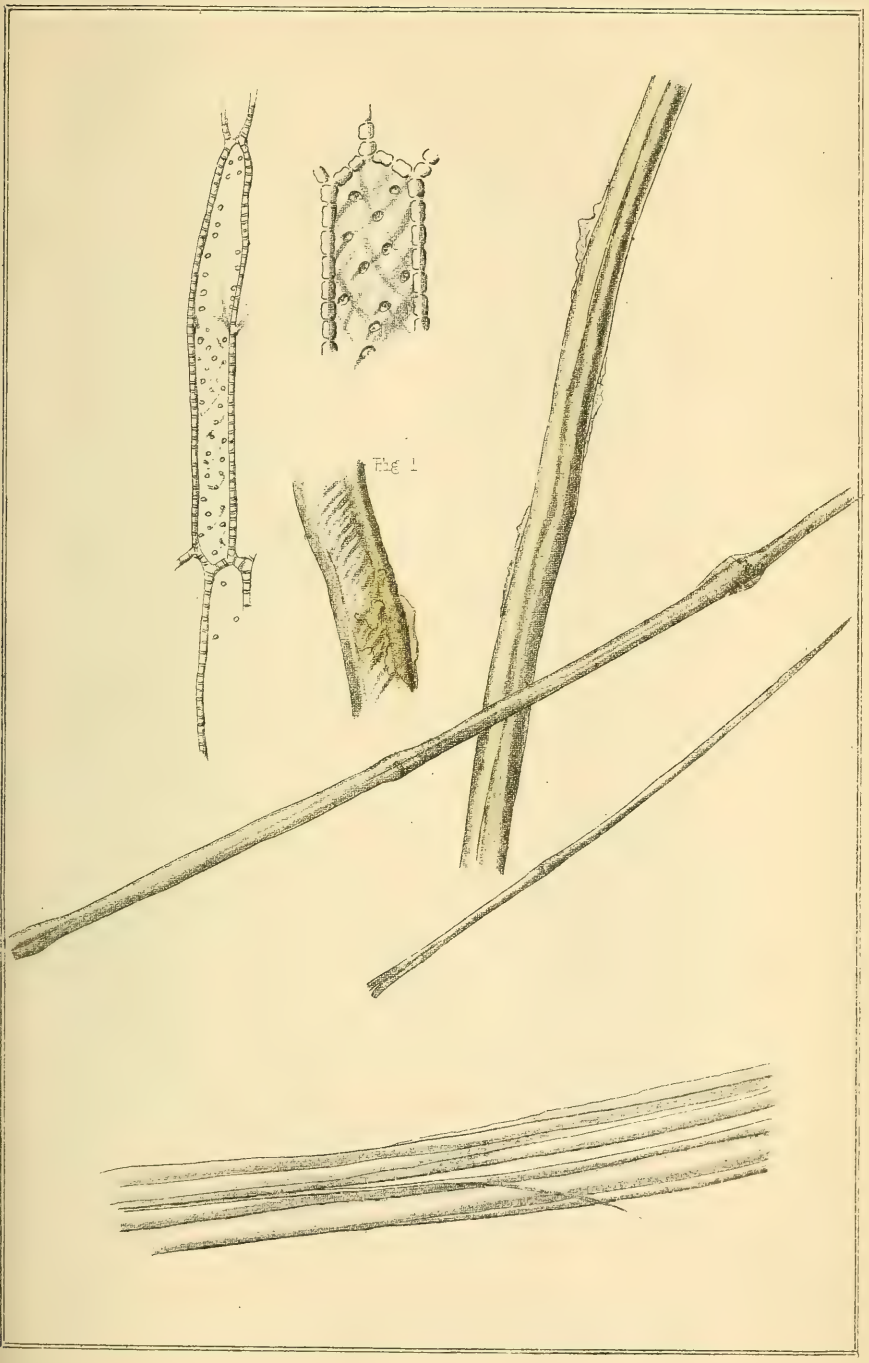
Fig 1

Treatment of Flax Yarn in the Cold.

69·402 grms. flax were covered with 750 cc. water, and left standing for seven days. Loss of weight, ·14 per cent.

Treatment of Flax with Water at a Boiling Heat.

22 grms. flax were boiled for six hours with a-quarter litre water. The light-brown liquor gave a faintly acid reaction with litmus paper; with hydrochloric acid it was decolourised with the production of a faint white opalescence; with ammonium hydrate it turned strongly brown; with neutral lead acetate it yielded a brown flocculent precipitate; with basic lead acetate a much more abundant yellowish precipitate.

Treatment of Flax Fibre with Hot Solution of Sodium Carbonate.

10 grms. fibre were boiled with 50 cc. of a 1 per cent. solution of sodium carbonate for sixteen hours, with addition of about 150 cc. water. The liquor was poured off, the fibre was washed with water, and the total bulk of the liquid made up to 350 cc. A sample treated with hydrochloric acid showed no more effervescence, but gave a brown gelatinous precipitate, the liquid being decolourised.

Treatment of Flax Fibre with Hot Sodium Sulphide Solution.

13 grms. flax fibre were boiled for twelve hours, with a reflex cooler, with 1 cc. of a strong sodium sulphide solution and a great deal of water; sulphuretted hydrogen was given off in considerable quantity. After twelve hours a lead solution did not produce in the brown liquor a black, but a brown precipitate.

Imperfect and incomplete as is the above work, yet it will, I trust, be found to add some little to the knowledge hitherto possessed of the action of several chemicals on the flax fibre, and of the character and constitution of some of the constituents of the plant; and though all the results which were obtained in the series of investigations undertaken are not given in this Paper, as it has been considered advisable to hold them over, owing to the want of time for their completion, and the great difficulty experienced in preparing sufficient quantities of the materials to be examined, yet I venture to hope that those already given will be found to possess considerable scientific interest.

In conclusion, I take this opportunity of thanking my friend Professor Dr. Lunge, of the Technischchemisches Laboratorium Eidgenössesches Polytechnikum, Zürich, through whose kindness I was permitted to pursue these investigations in that laboratory, and for whose valuable suggestions I am greatly indebted. I have also to acknowledge the valuable assistance which was afforded me by my private assistant, Dr. Zimmermann, now assistant in the laboratory of the University of Zürich.

LXVIII.—The Instruments in the Old Observatory at Peking.

By J. L. E. Dreyer, M. A.

[Read, June 13, 1881.]

When the missionaries of the Society of Jesus, in the seventeenth century, made their way to Peking, and startled the scientists of the Celestial Empire by their superior knowledge, they found in the eastern part of the city, on the rampart or wall surrounding it, an astronomical observatory furnished with several old instruments. Father Verbiest gained the confidence of the Emperor by repeatedly calculating beforehand the exact length of the shadow which a gnomon would throw at noon, and was authorised to have constructed six new large instruments. He has himself described these in a work with the following title:—"Astronomia Europæa sub imperatore Tartaro Sinico Cam Hy appellato, ex umbra in lucem revocata a R. P. Ferdinando Verbiest, Flandro Belga, e Societate Jesu, Academiæ astronomicæ in regia Pe Kinensi Præfecto" (Dillingæ, 1687, 4to).[1] The old instruments, which had to be removed to make room for his own, he seems to have paid no attention whatever to; at least he says nothing about them in his book, except (p. 47) that the Emperor gave him leave to construct new instruments—"Prioribus instrumentis Sinicis rudioris Minervæ, quæ jam a trecentis proxime annis speculam occupabant, inde amotis."

These despised instruments, as well as those erected by Father Verbiest, are still in existence. Some time ago I received from a friend residing in China, Mr. S. M. Russell, a series of photographs of these interesting scientific relics, and having had my attention drawn to them in this way, I thought that a short account of them might be read with some interest, particularly as there has not been much published about them hitherto.

The only plate in Verbiest's book represents the platform on which the six new instruments were mounted. It forms a square, with two small additions to the north-east corner, one of which is the head of the staircase leading up to the platform, while the other was occupied by a small house to which the observers could retire in bad weather. Next the staircase, on the north side of the platform, was a high mast, with a weathercock on it. Next to this was a sextant of six feet radius (*pedes geometrici*), evidently an imitation of Tycho Brahe's "Sextans bipartitus minoribus siderum distantiis inserviens,"[2] which it exactly resembles, with the exception that the arc is single. The arc

[1] This book seems to be rather scarce. Through the kindness of Father Perry, F.R.S., I have been able to examine a copy of it. Delambre gives an account of it in his *Histoire de l'Astronomie du Moyen Age*, p. 213, *et seq.*

[2] *Astronomiæ instauratæ Mechanica*, fol. D 3.

was divided to 15″,[3] and the observations were taken "per pinnacidia rimosa more Tychonico."[4] In the north-west corner was a quadrant (with the arc downwards), turning in azimuth round an axis which passed through the middle of the horizontal radius. In the middle of the west side of the platform was an azimuth circle, supported on four legs, and having in the middle a vertical axis, the upper end of which was joined by wires to the two ends of an alidade, which can be turned round the axis to any azimuth. In the south-west corner stood then a zodiacal armillary sphere, to which corresponded an equatoreal one in the south-east corner, while there was a revolving sidereal globe between them, six feet in diameter. Lastly, the middle of the east side of the platform was taken up by a low square tower, in the four corners of which four mandarins were posted, day and night, to observe the weather, meteors, &c., about which they prepared a daily report.

It would be needless to describe these instruments more in detail; they are true copies of the astronomical instruments devised and constructed by Tycho Brahe, and generally used long after his time. They were not furnished with telescopes. The photographs show with certainty that they have been moved about since they were mounted in 1673, as they do not now occupy the places they did then (as described above). Besides, there has been added a new instrument to the collection (but *when* I have not been able to find out), viz., another azimuthal quadrant. This instrument differs from all the others in not being profusely ornamented with dragons and serpents; on the contrary, it is in very pure European style. Possibly it was constructed some time during the eighteenth century, when the missionaries felt more at home, and less afraid of dispensing with what looked to them as heathen symbols.

Besides these instruments on the roof of the old observatory there are still in existence two others, equally large and imposing-looking, which are placed inside low brick enclosures in a kind of yard adjoining the observatory. These I had also (as I believe they have generally been) attributed to Verbiest, as they were not very different in their general appearance from his instruments. However, when I came across a Paper by Mr. A. Wylie—"The Mongol Astronomical Instruments in Peking"[5]—I found that they were in fact two of the old instruments which Verbiest removed from the observatory. When they were placed in their present positions appears to be unknown; Gaubil states that he was not permitted to get a look at them, and that they were kept in a closed room.[6] This agrees with what Father Le Compte says, who was in Peking about the year 1688, and who

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[3] Probably by means of transversals.
[4] *Astronomia Europæa*, p. 52.
[5] *Travaux de la 3e Session du Congrès International des Orientalistes*, Vol. ii.
[6] Souciet, *Observations Mathématiques*, &c., T. ii., p. 108.

saw them through a window "close set with iron bars."[7] They are now easily accessible.

According to Mr. Wylie, well-informed natives state that these instruments were made during the Yuen dynasty, and he quotes a Chinese description of Peking, in which the observatory and four large instruments (two of which, from the description, can be identified as the two still extant) are said to have been constructed in the year A.D. 1279. This date brings us back to one of the most interesting periods of Chinese history, as it was in 1279 that Koblai Khan, the great Mongol monarch, and grandson of Djengis Khan, finished the conquest of China, and moved his residence to the new city Taydo, now called Pe-King. Very different from his ancestors, Koblai was a monarch who favoured science and arts, and he supported and protected the astronomer Ko Show-King, who had first had the control of the waterways of the empire, but whom he, in 1276, appointed to examine the system of chronology then in use. Ko Show-King got the observatory built, and constructed a number of instruments, all of which are counted up in the *Yuen She*, or History of the Yuen (*i.e.*, Mongol) dynasty. The descriptions, as translated by Mr. Wylie, are in most cases very difficult to understand, except in the cases of the instruments *Keen e*, or equatoreal, and *Ling-lung e*, or armillæ—as these are the two standing at the present moment in the courtyard of the old observatory. About this identity there can be no doubt, as the above-mentioned description of Peking expressly states that the *Keen e* and the *Ling-lung e* were removed in 1673 from the platform, and stored away at the foot of the building. Gaubil (*l. c.*) also says that the instruments which in his time were kept "dans une salle fermée" were made by Ko Show-King.

It would only tire the reader if I were to reproduce the whole of the elaborate description of the Chinese writer, particularly as this is only intelligible when compared with a picture of the instruments. What I wish to call attention to in these pages is, that we have here two remarkable instances of how the Chinese people often came into possession of great inventions many centuries before the western nations enjoyed them. We find here in the thirteenth century the equatoreal armillæ of Tycho Brahe, and better still, an equatoreal instrument, like those "armillæ æquatoriæ maximæ" with which Tycho observed the comet of 1585, as also fixed stars and planets.[8]

It is well known that armillæ have been in use in China very early, and probably before the astronomers at Alexandria commenced using instruments with graduated circles. It is particularly stated by Father Gaubil that Sse-Ma-Tsien, about the year 100 B.C., mentions some *old* instruments, with circles of two feet five inches

[7] *Memoirs and Observations Topographical* (London, 1697), p. 65.
[8] *Astr. Inst. Mechanica*, fol. D 2.

diameter. It is added, that the motions of the stars were referred to the Equator, and that there was no instrument in use for observing the motion on the ecliptic. This would seem to indicate, that the Chinese astronomers, who in so many respects were behind the Greeks in their knowledge, had actually invented equatoreal armillæ (which were not in use in Europe before Tycho Brahe), and used them instead of the less convenient and unsymmetrical "armillæ zodiacales," invented by Hipparchus, and still used even by Walther and Regiomontanus.

But even if it be admitted that the description of these old instruments is much too vague to found on it a claim for the Chinese astronomers of the time before Christ as being the inventors of the equatoreal armillæ, at any rate it is now certain that Ko Show-King, the astronomer of Koblai Khan, constructed such armillæ three hundred years before Tycho Brahe. It has been suspected by the younger Sédillot[9] that Alhazen knew equatoreal armillæ; but even if this was really the case, it would probably be carrying conjecture too far to suppose the Mongol astronomer to have heard of this occidental invention.

The instruments of Ko Show-King were examined in one of the first years of the seventeenth century by the Jesuit Matteo Ricci (who died in China in 1610),[10] who speaks of them as being counterparts of some he had seen at Nanking, and described at some length. Mr. Wylie (*l. c.* p. 18) quotes the following part of this description from Colonel Yule's translation in *The Book of Ser Marco Polo* (Vol. ii.):—"A second instrument was a great sphere, not less in diameter than that measure of the outstretched arms which is commonly called a geometric pace. It had a horizon and poles; instead of circles, it was provided with certain double hoops, the void space between the pair serving the purpose of the circles of our spheres. All these were divided into 365 degrees and some odd minutes.[11] There was no globe to represent the earth in the centre, but there was a certain tube, bored like a gun-barrel, which could readily be turned about, and fixed to any azimuth, or any altitude, so as to observe any particular star through the tube, just as we do with our vane-sights."

This description evidently refers to an imitation of the equatoreal armillæ now in the courtyard of the Peking Observatory. The photograph shows in fact very distinctly that all the circles are double, separated by a narrow interval. Whether this interval was intended for the hollow tube to slide in, or whether the circles were only made double in order to strengthen the instrument, it is not easy to see. Perhaps both these objects were kept in view. The tube appears to have four longitudinal slits in it, 90° apart, and interrupted near the

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[9] *Prolégomènes des Tables Astronomiques d'Olough-Beg.* Paris, 1847, p. cxxxiv.
[10] Jöcher's *Gelehrten-Lexicon*, Vol. iii.
[11] It will be remembered that the Chinese divided the circle into $365\frac{1}{4}°$.

middle of the tube; but what they were intended, for I cannot make out.

The other instrument of Ko Show-King, the *Keen e*, which I have above likened to Tycho Brahe's armillæ maximæ, and which is by far the more interesting of the two, is described at great length in the *Yuen She*. It consists of a double declination circle, six feet in diameter, each circle two inches wide, and an inch in thickness. The interval between the two circles is one inch, and they are connected at four points 90° apart. "The degrees and minutes" are marked round the circumference (Father Matteo says, by prominent studs of iron, which could be felt in the dark). There is no polar axis, but two parallel stretchers, four inches on either side of the polar pivots, and joined in the middle by a transversal brace, in the middle of which is the pivot for the alhidade. The latter has pointed ends and two sights, with a round aperture in the middle, three-fifths of an inch in diameter, "with a fiducial line down the centre." The south-pole pivot is in the centre of a diurnal circle, also six feet in diameter, and divided into twenty-four hours. On this circle, which is let into the mounting of the instrument, slides an equator-circle of the same diameter, "divided into degrees and minutes, according to the twenty-eight constellations." The following particulars I copy *verbatim* from Mr. Wylie's translation :—"A hole is made through the centre of the north-pole pivot. At the bottom of this hole a transverse hole is drilled from side to side. A thread is passed up the centre, bent over, and brought out at the two transverse holes, and fastened at both sides. Three lengths of thread are passed through the hole, and fastened. At the upper and lower ends respectively threads are carried down to the two ends of the index bars (*i.e.* the alidade), and passed through a hole, being sunk into the under side of the index bar, along the centre line of which a groove is cut to receive the thread. It is then carried along the middle of the slit to the centre of the index bar, and through a hole in the middle part the thread is passed up from the lower side of the index bar, and fastened."

This thread or wire has probably disappeared from the instrument centuries ago.

Mr. Wylie's Paper contains two lithographs of the two instruments, but not seen from a good point of view, and consequently not showing all the details well. I trust the reader will have learned sufficient from the above descriptions to acknowledge the historical interest attached to these old instruments, which anticipated some of the ideas of the great Danish astronomer three centuries before his time.

LXIX.—Preliminary Report on Soundings taken in Lough Gill, Sligo. By Edward T. Hardman, F. C. S., &c., H. M. Geological Survey.

[Read, June 13, 1881.]

A grant of fifteen pounds having been voted by the Royal Irish Academy towards carrying out the above object, the work was entered on during a part of last year (1880). Owing to various circumstances it was not commenced until somewhat late in the season, but advantage was taken of a continuance of favourable weather to obtain a great many soundings. These have been as yet confined to lines of sections along and across the lake, and in some of the principal bays and inlets of it, as well as depths ascertained around some of the various islands.

In this way a good deal of information has been obtained as to the form of the lake-bottom, and many interesting facts noted, which, when more fully followed up, will, it is expected, help considerably to elucidate the physical history of the lake.

It is proposed this year to continue these soundings, and to endeavour to obtain a series of depths along the shores at regular intervals from it.

The principal section runs right along the centre of the lake from end to end, beginning at the entrance of the River Garavogue, passing by Church Island, and continuing on to Shriff Bay. The depths along this line are considerable in some places; and one thing very noticeable is a tendency to very sudden differences of level in short distances. It is not uncommon to find within a distance of 400 feet a difference of depth of 30 feet or more.

The principal depths on this section are:—Between Cottage Island and Church Island, 65 feet; one mile from the latter island, 96·38 feet; a little further on eastward, 97·6 and 99 feet; then 105 and 116 feet, the last being the greatest depth yet found in the lake. This lies a little more than one mile from the east end of Church Island, and one mile and three-quarters from the east end of the lake. From this point to the end of the section at Shriff Bay the lake shallows again.

It should be noted that the depths given here are those actually taken. But as the water was at the time exceptionally low, and at least ten feet below its ordinary winter level, it would be necessary to add five feet for the average depths of the lake. The greatest depth would, therefore, be about 121 feet.

Another section was taken parallel to the last, and south of it, along the shore, from Aghamore Bay, through Goat Island, to Slish Wood. The depths along this line are moderate as far as Goat Island, where they suddenly increase. The northern shore of this island shelves down very rapidly, forming a deep cliff, which, at thirty yards from the shore, is 63 feet in depth. Further on the

depth is 88 feet, and half a mile east of the island, just opposite the entrance of Bunowen Bay, the sounding was 103·7 feet.

Two sections were run along the shores of Bunowen Bay, proving the water even close to the shore to be very deep, in some places one hundred yards only from the shore being from 35 to 47 feet.

Sections were run from this bay to the south of Church Island, proving some considerable depths. A remarkable one is about sixty yards south of the spit of land forming the southern point of the island, where there is a sudden drop of 84 feet in hard rock. In fact, all along the southern side there is very deep water, while that on the northern is very shallow.

Other sections were run from Church Island to Leggamore Bay (Holywell), and from this to Wolf Island, near the Garavogue river. The greatest depths in these were 34 and 41 feet respectively.

Another section was obtained from Toberconnel Bay, southwards, towards Rockwood, in the narrowest part of the lake. The depths here are considerable—half a mile from the shore they reach 99 feet, and a little further south 96 feet.

Besides the above, several isolated soundings were taken, but these possess at present no particular interest.

The season being then too advanced, the work was stopped. It will be continued this summer, and it is hoped that a full Report, with chart and sections, will be ready for presentation to the Academy during the next Winter Session.

Summary of Facts.—It would be premature as yet to enter into the geological aspects of the subject, but the following points may be noted:—

1°. The great and frequently-recurring irregularity of the bottom of the lake.

2°. The preponderance of depth (with few exceptions) on the south side, along which a great line of fault runs.

3°. That many of the deeps of the lake nearly coincide with the direction of known lines of faults in the shore rocks.

4°. That while the direction of the ice-flow, as indicated by the markings, in the district immediately around the lake is towards the N.W. or N.N.W. (that is, across it), the principal line of the lake is in an east and west direction.

5°. That the numerous small islands in the lake form sub-aqueous cliffs, which cannot be regarded as due to ice action, seeing that the "crag," or cliff, faces indifferently north, south, and east.

On the whole, therefore, the evidence at present seems to point to the origin of the lake as due to faults and subsidences in the first place, followed by chemical erosion of the limestone rocks along the lines of fault. That ice-action assisted in the details of the carving out to some extent there can be little doubt; but these matters will be fully entered into in a subsequent Report.

LXX.—REPORT ON THE ROCKS OF THE FINTONA AND CURLEW MOUNTAIN DISTRICTS. By G. H. KINAHAN, M.R.I.A., with Palæontological Remarks by W. H. BAILY, F.G.S. (With Plates XVI. and XVII.)

[Read, April 12, 1880.]

INTRODUCTION.

THE committee commenced operations in the neighbourhood of Pomeroy, and worked south-westwards to Lisbellaw, Drumshambo, Boyle, and Ballaghaderreen; while, for comparison, a traverse was made of the rocks in the Croaghmoyle, Toormakeady, Clew Bay, and Killary Bay districts.

As the fossils are an important element in the inquiry, on account of the occurrence of an assemblage of English Cambro-Silurian forms at certain places in the Irish Silurians, a list of those recorded from different areas is given in a tabular form, whereby those common to the different localities can be seen at a glance.

The report is divided into three parts:—*First.* A discussion of the Pomeroy and Lisbellaw fossiliferous rocks. *Second.* A Table of the Cambro-Silurian fossils found at Pomeroy and Lisbellaw, with those found in the different Irish Silurian tracts. *Third.* A discussion of the Silurian rocks, commonly called "Lower Old Red Sandstone," of Tyrone, Fermanagh, and the Curlew Mountains, with their relations to the Silurians of S.W. Mayo and N.W. Galway.

PART I.—(*In Abstract.*)

FOSSILIFEROUS ROCKS IN THE NEIGHBOURHOOD OF POMEROY.

Near Pomeroy are three distinct groups of rocks (neglecting the Carboniferous), namely—

3.	Red, purple, and greenish sandstones, conglomerates, and sandy shales, with interstratified masses of eurite (basic felstone), tuff, breccia, and, in places, green shales and limestone.	"LOWER OLD RED SANDSTONE" (Silurian).
2.	Green, grey, and bluish shales, slates, and grits; a few of the latter being quartzose and conglomeritic, while some of the shales are calciferous, and many of them fossiliferous.	POMEROY SERIES.
1.	Metamorphic sedimentary and eruptive rocks, with intrusions of granite, &c.	ARENIG GROUP.

The reasons for classifying the rocks of group 1 as Arenig are given in a Paper already read before the Academy, "On some supposed Cambrians in Co. Tyrone and N.E. Mayo."[1]

Attention is now directed to the rocks of the Pomeroy series, which are evidently much newer than the metamorphic rocks north of them (*Arenig group*), although both groups are called Lower Silurian in the Geological Survey Memoir descriptive of the district. The fossils of this series are of types indicating an age similar to the English Caradoc-Bala series: this, although important, is not conclusive evidence, on account of the zones of English Cambro-Silurian fossils occurring in the Irish Silurians. All the evidence on both sides was therefore given.

The point of greatest interest with respect to the Pomeroy series is to determine the relation between them and the overlying ones of the "Lower Old Red Sandstone" type: we believe this to be one of unconformability. Portlock, on the contrary, says in his Report that the latter seem to lie conformably on the former. His boundary of the Pomeroy strata has been left substantially unaltered by the Geological Survey. If the southward part of his boundary between the two groups now in question in Shanmaghry were rightly placed, his conclusion would, in all probability, be correct, because the rocks above and below the geological horizon at that place evidently form a continuous sequence. But the more detailed maps which accompanied our Report (of which Pl. XVI., fig. 1, is a reduction) show that Portlock's boundary near Aghafad is probably incorrect, as the faults that shift the boundary in that part are ignored. He has there included in the Pomeroy series rocks which really belong to the "Lower Old Red Sandstone" type. We believe that the boundary should be north of Shanmaghry, viz., at Aghafad (see Pl. XVI., fig. 2). The section at that place is the only nearly continuous one to be seen; and although it is not quite conclusive, it certainly suggests an unconformability at the red conglomerate there exposed. Elsewhere Portlock's boundary would imply an unconformability between the two groups of strata in question. The long narrow strip of "Lower Old Red Sandstone" which he supposed to extend along the east side of the Pomeroy strata between them and the Carboniferous sandstone, if it really existed, would in all probability lie unconformably on the Pomeroy strata. But we cannot avail ourselves of this confirmation of our position, for all the evidence that we could collect goes to show that the Carboniferous sandstone lies directly on the Pomeroy strata, without any intervening "Lower Old Red Sandstone." Along the western side of the exposure of the Pomeroy strata, where Portlock's boundary between the two groups now in question is correctly drawn, no material for a conclusion, one way or the other, respecting the relation of those groups can be obtained, on account of the numerous faults in that neighbourhood.

[1] *Proceedings*, Royal Irish Academy, ser. II, vol. iii., *Science*.

The reasons for and against the unconformability between the rocks of the Pomeroy series and those of "Lower Old Red Sandstone" type may be tabulated as follows:—

FOR.	AGAINST.
The Aghafad conglomerate blocks seem to be the untransported *debris* of the basal bed of the "Lower Old Red Sandstone"; and if this dips at a similar angle to the rocks a little way off towards the south, all ought to lie unconformably on the fossiliferous rocks to the north.	All the rocks in the Aghafad section have a similar strike, and dip in one direction. The rocks in Lurganeden, a little south of the Aghafad conglomerate, are very similar, if not lithologically identical, with some of the rocks of the Pomeroy series.
As the rocks at present appear, in the north-east corner of Cornamaddy, there seems to be an unconformability between the two series.	In the valley at the N.E. of Cornamaddy there are evidently various concurrent faults; therefore the rocks exposed may not fairly reveal the true position of the strata.
The general strike of the rocks of the Pomeroy series would suggest that they extended unconformably under the later rocks to the west. Moreover, to the westward, about two miles N.E. of Six-mile-Cross, adjoining the Camowen river, there is a small exposure of rocks, very like those of the Pomeroy series, standing at a high angle and striking at the later rocks. Unfortunately this exposure is so small, that it is impossible to say for certain the true age of these rocks.	If those rock tracts which are undoubtedly faulted be neglected, in the other places the strike and dip of the rocks of both series appear very similar.
The rocks of the Pomeroy series appear to be much more broken up and displaced by faults than the overlying rocks.	Argillaceous rocks may be much more broken up and displaced by faults than others of the same group which are arenaceous.
The fossils of the Pomeroy series are almost entirely of English Caradoc-Bala types (Cambro-Silurian).	Fossils of Caradoc-Bala type occur in some zones of the Irish Silurians of Kerry, Galway, and Mayo; and therefore the occurrence of such is not conclusive evidence in Ireland that the strata containing them are Cambro-Silurian.
To the S. W. of the area of the rocks of the "Lower Old Red Sandstone" type, at Lisbellaw, in the county of Fermanagh, there are rocks very similar to those of Pomeroy, and containing some fossils identical in species. On these Lisbellaw rocks the rocks of the "Lower Old Red Sandstone" type lie unconformably.	It is possible that the rocks of the "Lower Old Red Sandstone" type may be in part equivalents of the Glengariff grits, that is, of the "Passage beds" between the Silurian and Carboniferous. In such case it would be possible that although the rocks form a continuous sequence at Pomeroy, yet elsewhere, on account of an overlap, higher or later beds might lie unconformably on the Lisbellaw rocks.

The balance of the evidence was considered by us to be favourable to the unconformability between the rocks of the Pomeroy series and

the overlying ones of the "Lower Old Red Sandstone" type, and therefore to be confirmatory of the *primâ facie* presumption afforded by their fossils that the rocks of the Pomeroy series are of Cambro-Silurian age.

Lisbellaw Fossiliferous Rocks.

Two groups occur to the northward of Lisbellaw, the later lying unconformably on the older.

2.	Red sandstone and sandy shales, with some green beds. At Lisbellaw there are massive conglomerates with inliers of green shales. The massive conglomerates appear to be very local, as they do not occur to the north-eastward or westward.	"Lower Old Red Sandstone" (Silurian).
1.	Grey to dark blue shales, slates, and grits, with, in some places, green grits; some beds fossiliferous. They are occasionally metamorphosed in part as if by paroptetic action.	Cambro-Silurian.

The rocks of group 1 occupy only a small area, in which there are few exposures; they are fossiliferous near the hamlet called the Slate Quarry. From the rocks seen and a knowledge of other Irish Cambro-Silurians it is suggested that they are probably on a somewhat lower geological horizon than the rocks of the Pomeroy series. From a letter received from Mr. W. Staunton, it would appear that this authority, judging from the contained graptolites, considers the rocks of the Pomeroy series to be the equivalent of the Lower Llandovery, or the uppermost rocks of Cambro-Silurian age.

PART II.

Palæontological Notes. By W. H. Baily, F.G.S.

The following Table includes a complete list of recorded species from the localities mentioned at the head of each column: to these are added some others, the result of our visit to the districts we proposed to investigate.

The first column (No. 1) is that of the Pomeroy district, Co. Tyrone, celebrated for the beauty and variety of its fossils. The large number of 111 species are included in this list from that comparatively small area of strata. Amongst them the Trilobites, an extinct order of crustacea, number 27 species; Brachiopoda, 20 species; Mollusca-Conchifera, 14 species; Gasteropoda, 10 species; Pteropoda, 5 species; and Cephalopoda, 15 species: all these are Lower Silurian fossils of Caradoc-Bala types. The majority are described and figured in Portlock's Report on the Geology of Londonderry, Tyrone, &c. The Trilobites include species, some of which, as *Cybele rugosa, Remopleurides Colbii, Phacops Brongniartii, P. truncato-caudatus, Trinucleus concentricus*, and *T. seticornis*, being identical with those of Caradoc or Bala age from England and Wales: others, such as *Harpes Dorani, H. Flanagani, Ampyx rostratus, Asaphus gigas, A. radiatus, A. rectifrons, Illænus Portlockii, Staurocephalus globiceps, Stygina latifrons*, and *Bronteus Hibernicus*, are exclusively Irish species. The Brachiopoda are next in importance to the Trilobites in respect to the number of forms; amongst them, *Lingula brevis, Orthis fallax*, and *O. intercostata*, are the only species at present known to be exclusively Irish; the others, although some of them, such as *Discina oblongata, Orthis biforata, O. crispa, O. porcata, Strophonema corrugatella, S. expansa, S. grandis*, are eminently characteristic of Irish strata, also occur in England and Wales, and some of them in Scotland. Bivalve and univalve Molluscan shells (Conchifera and Gasteropoda) are not unfrequent in these grey schists. Amongst the former, Nucula-like shells, Ctenodonta, are plentiful, as many as six species being enumerated; it is very possible, however, that some of them may prove to be merely variations of form; Modiolopsis and Ambonychia are also frequent. Of the Gasteropoda, or univalve shells, Euomphalus and Murchisonia are the most frequent. The Nucleobranchiata include three species of Bellerophon, and the Pteropoda two species of Conularia, the remarkable spirally-coiled *Ecculiomphalus Bucklandi*, and two species of Theca. Shells of Cephalopoda are frequent, particularly Orthoceras, which is represented by twelve species, four of which—*O. breviconicum, O. elongato-cinctum, O. perannulatum*, and *O. Pomeroense*, are confined to this district; the curved *Cyrtoceras inæquiseptum* is exclusively an Irish fossil, although it has also been found in beds of similar Caradoc age at Tramore Bay, Co. Waterford.

A sponge doubtfully referred to Cliona, a few corals, and some characteristic Graptolites, complete the list from the highly fossiliferous strata of Pomeroy and neighbourhood.

The fossils described from Lisbellaw, Co. Fermanagh (No. 2 of the Table), for the most part by General Portlock in the Report before cited, number ten species only, four of them being Graptolites, which, like those of Pomeroy, occur in dark-grey slates: three of these also occur at Pomeroy, one only, *Graptolithus sagittarius*, up to the present not having been recorded from that locality. The Bivalve shells, *Mytilus cinctus* and *Cardiola semi-rugata*, are exclusively confined to Caradoc strata, the first-named species also occurring in precisely similar rock at Pomeroy. The Cephalopod shell *Potericeras approximatum* is likewise a typical Caradoc species, and exclusively confined to that formation.

The fossils discovered in the course of this investigation in rocks previously described as Old Red Sandstone, at Cashelduff, N. W. of Ballaghaderreen, Co. Mayo, N. E. (No. 3 of Table), are undoubted Upper Silurian (as are other well-known fossils at Uggool, &c., in the immediate neighbourhood to the S. W.), and of Upper Llandovery types. Seven species were identified from the collection made at this place on the occasion of our visit; four of these have a geological range from Caradoc or Bala to Upper Llandovery strata, two of them continuing on into Wenlock strata. Of the remaining two species one, *Pentamerus oblongus*, is confined to Llandovery strata, the other, *Stricklandinia lirata*, commencing in the Lower Llandovery, continues on to the Wenlock; both are, however, highly characteristic of Llandovery strata.

We have included in the Table (Nos. 4, 5, 6, 7 and 8) certain Lower Silurian fossil localities in the West Connaught district, counties of Mayo and Galway, and another (No. 9) from the Dingle district, Co. Kerry, for comparison. Column No. 4 tabulates the fossils from cliffs above Lough Bellawaum, Co. Mayo, all being of Caradoc-Bala types. Eleven species are enumerated from this locality (Explanatory Memoir of the Geological Survey to Sheets 83 and 84, p. 31), one being of doubtful identification: seven of them are Brachiopods, one Mollusca-Conchifera, two Nucleobranchiata, and one Cephalopod. Three of these fossils, viz., *Leptæna sericea*, *Orthis testudinaria*, and *Bellerophon bilobatus*, range from Llandeilo to Llandovery strata; three, viz., *Lingula ovata*, *Porambonites intercedens*, and *Ctenodonta transversa*, are confined to Caradoc strata; and three others, viz., *Orthis biforata*, *Bellerophon trilobatus*, and *Orthoceras ibex*, range from the Caradoc to Wenlock and Ludlow strata; all, therefore, are present in strata of Caradoc or Bala age, although some of the species commence in older formations, and continue on into newer. The fossils collected from the S. E. side of Mweelrea Mountain, in the county of Mayo (column No. 5), also indicate Caradoc strata: four species only are enumerated, all of which likewise occur in the preceding locality.

At Uggool, Killary Harbour, Co. Mayo (column No. 6), the same fossiliferous strata of Caradoc age are prevalent, the number of forms being considerably increased. Seventeen species from this locality are included in the list; amongst them, one coral, *Heliolites tubulatus*, a species ranging from Caradoc to Wenlock; a crinoid referred to Glyptocrinus, five species of Brachiopoda, three species of Gasteropoda, two Nucleobranchiata, all being characteristic of Caradoc strata; three of Pteropoda, exclusively Caradoc species; and two Cephalopods, both of them having a geological range from Caradoc to Ludlow strata.

At two places N. E. and S. W. of Toormakeady, in the counties of Galway and Mayo (column No. 7), fossils of Caradoc age occur in pink and grey brecciated limestone, very similar to that of the Chair of Kildare, both in lithological character, and the preponderance of Trilobite remains. The fossils consist of Crinoidal remains referred to Glyptocrinus, four species of Trilobites, of which three, *Cheirurus bimucronatus*, *Cybele verrucosa*, and *Illænus Bowmanni*, commence in Caradoc strata, the two last-named species continuing on to the Llandovery and the first-named one to the Wenlock, whilst the fourth, *Phacops caudatus*, has hitherto been recorded as commencing in Llandovery strata only, passing up into the Ludlow series. Here, however, we have it associated with undoubted Caradoc fossils. From these localities eight species of Brachiopoda are enumerated, all of which are of Caradoc types, although some of them commence in the Llandeilo formation, and others continue on to Wenlock, and even Ludlow strata.

From Lough Muck, Co. Galway (No. 8), only three species are recorded, all similarly indicative of Caradoc strata, viz., *Graptolithus tenuis*, having a geological range from Llandeilo to Caradoc, and the Gasteropod Mollusca *Holopea concinna*, and *Murchisonia obscura*, both confined to Caradoc strata.

The remaining column (No. 9), from Anascaul, Co. Kerry, includes but three species—a Crinoid, the Polyzoan (*Ptilodictya dichotoma*), and a Pteropod (*Conularia elongata*); they are, however, highly characteristic fossils of the Caradoc formation.

Part II.—Baily's List of Fossils.

The Fossils of all the columns except No. 3 are of Caradoc-Bala forms, those of No. 3 being of Upper Llandovery types.

Names of the Fossils.	1. Pomeroy, Co. Tyrone.	2. Lisbellaw, Co. Fermanagh.	3. Boundary of townlands Casheluff and Cranmore, N.W. of Ballaghaderreen, N.E. of Co. Mayo.	4. Cliff above Lough Bellawaum, Co. Mayo.	5. S.E. flank of Mweelrea, Co. Mayo.	6. Uggool, Killary Harbour, Co. Mayo.	7. N.E. and S.W. of Toormaleady, Co. Galway.	8. Lough Mask, N.W. of Co. Galway.	9. Anascaul Beds, Dingle, Co. Kerry.
Protozoa.—*Spongida.*									
? Cliona antiqua,	*								
Hydrozoa.—*Graptolitidæ.*									
Diplograptus folium,	*	*							
,, pristis,	*	*							
Graptolithus sagittarius (Hisingeri)		*							
,, Sedgwickii,	*	*							
,, tenuis,	*							*	
Actinozoa.—*Zoantharia.*									
Cyathophyllum (Petraia) elongatum,	*		*						
Favosites fibrosus,	*								
Halysites catenularius,	*								
Heliolites interstinctus,	*						*		
,, tubulatus,									
Echinodermata.									
Glyptocrinus lævis,	*								
,, sp. indet,	*						*	*	*
Palasterina ,,	*								
Crustacea.—*Trilobita.*									
Amphion pseudo-articulatus	*								

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LIST OF BAILY'S FOSSILS—*continued.*

NAMES OF FOSSILS.	1. Pomeroy, Co. Tyrone.	2. Lisbellaw, Co. Fermanagh.	3. Boundary of townlands Casheliduff and Cranmore, N.W. of Ballaghaderreen, N.E. of Co. Mayo.	4. Cliff above Lough Bellawaum, Co. Mayo.	5. S.E. flank of Mweelrea, Co. Mayo.	6. Uggool, Killary Harbour, Co. Mayo.	7. N.E. and S.W. of Toormakeady, Co. Galway.	8. Lough Mask, N.W. of Co. Galway.	9. Anascaul Beds, Dingle, Co. Kerry.
MOLLUSCA.—*Brachiopoda—continued.*									
Leptæna tenuicincta,	*								
,, transversalis,	*								
,, quinquecostata,									
Lingula attenuata,	*								
,, brevis,	*								
,, ovata,	*								
Orthis biforata,	*								
,, calligramma,	*		*	*		*			
,, crispa,	*			*	*	*			
,, elegantula,									
,, fallax,	*								
,, insularis,	*								
,, intercostata,	*								
,, porcata,				*	*	*	*		
,, testudinaria,									
,, vespertilio,					*				
Porambonites intercedens,						*	*		
Rhynchonella æmula,	*								
,, borealis,	*								
Strophonema corrugatella,	*								
,, expansa,									
,, rhomboidalis (depressa),		*							
,, grandis,	*								
Lamellibranchiata.									

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BAILY'S LIST OF FOSSILS—*continued.*

NAMES OF THE FOSSILS.	1. Pomeroy, Co. Tyrone.	2. Lisbellaw, Co. Fermanagh.	3. Boundary of townlands Casbelduff and Craumore, N.W. of Ballaghaderreen, N.E. of Co. Mayo.	4. Cliff above Lough Bellawaum, Co. Mayo.	5. S.E. flank of Mweelrea, Co. Mayo.	6. Uggool, Killary Harbour, Co. Mayo.	7. N.E. and S.W. of Toormakeady, Co. Galway.	8. Lough Mask, N.W. of Co. Galway.	9. Anascaul Beds, Dingle, Co. Kerry.
Pteropoda.									
Conularia elongata,	*								*
,, Sowerbyi,	*			*					
Eccultiomphalus Bucklandi,	*								
Theca reversa,	*								
,, triangularis,	*								
Cephalopoda.									
Cyrtoceras inæquiseptum,	*								
Lituites (sp. cornu arietis, Portl.),	*								
Poterioceras (Phragmoceras, Portl.), approximatum,	*	*							
Orthoceras bilineatum,	*								
,, breviconicum,	*								
,, elongato cinctum,	*	*							
,, filosum,	*								
,, gracile (Portl.),	*								
,, Ibex,				*		*			
,, incertum,	*								
,, per-annulatum,	*								
,, Pomeroense,	*								
,, subcostatum,	*								
,, subundulatum,	*								
,, tenuicinctum,	*					*			
,, tumidum,	*								

PART III.—(*Abstract.*)

Lithologically the Irish Silurians may be divided into *coarse accumulations* ("red arenaceous" type) and *fine accumulations* ("green and grey argillaceous" type), generally containing marine fossils; the former being the rocks commonly called "Lower Old Red Sandstone," and by Jukes, "Dingle or Glengariff Grits." This division, however, is no indication of relative age; for although the rocks of the first type are more often above the others, this is not always the case. On account of the Silurian strata having been deposited in separate basins, the littoral rocks, usually coarse, must be on different horizons, as shown in the plate of vertical sections (Plate XVII.).

The age of the British rocks called "Lower Old Red Sandstone" has lately been prominently brought forward by Dr. Archibald Geikie, in his Paper "On the Old Red Sandstone of Western Europe;"[1] and as his conclusions intimately concern the Irish rocks, they are now mentioned.

Geikie considers the "Lower Old Red Sandstone" of Great Britain to be a part of the same sequence as the typical Silurians, and he suggests five "Basins of Deposition":—

1. Lake Orcadia Basin.
2. Lake Caledonia, or the Middle Scottish Basin.
3. Lake Cheviot Basin.
4. The Welsh Lake Basin.
5. Lake of Lorne Basin.

If these are extended into Ireland, the second might be called the *Ulster and Connaught Basin*, and the fourth the *South Munster Basin*. The last extends westward into Waterford, Cork, and Kerry; it is thus briefly mentioned on account of its having to be referred to again in the present inquiry.

The western extension of the Caledonian Basin is first met with in Ireland, near Cushendun, on the east coast of Antrim, in a small tract of conglomerate, apparently a portion of the shore beds; but westward and southward the associated rocks are covered up by Mesozoic and Cainozoic rocks; in addition to which, at Lough Neagh they must be shifted or "heaved" southward by the N. and S. faults of that valley.

In south-east Londonderry, in the neighbourhood of Draperstown and Moneymore, there are red arenaceous rocks of uncertain age, which probably may hereafter be found to be outlying portions of this basin; but further southward, in Tyrone and Fermanagh, the large tract (*Fintona district*) of "Lower Old Red Sandstone," appearing from under the Carboniferous rocks S.E. of Pomeroy and extending westward to the Carboniferous rocks of the Erne Valley, seems un-

[1] *Trans. Roy. Soc. Edin.*, vol. xxviii.

questionably to belong to it. These rocks, as previously mentioned, lie unconformably on the Arenig rocks to the north, and on the Cambro-Silurians at Pomeroy and Lisbellaw. To the eastward, near Pomeroy, and to the westward, in the Topped Mountain district, these rocks are usually of a red colour and very arenaceous; but S.E. of Six-mile-Cross, where they appear to be best developed, there are, below, red arenaceous rocks with subordinate limestones and shales; above, there are green sandstone and shales, with a few limestones; while higher up there seem to be red arenaceous rocks. This, as will hereafter appear, is very similar to the section in the Ballaghaderreen district, Co. Mayo.

Further westward the rocks of this basin were again shifted or "heaved" southward by the faults of the Upper Lough Erne and parallel valleys, they appearing from under the Carboniferous S.E. of Lough Allen, near Drumshambo (Co. Leitrim). They are cut off on the westward by a down-throw to the west; but they shortly again appear east of Lough Key and in the Curlew Mountain district, the rise of ground from Lough Key, past Lough Gara, to the country N.W. of Ballaghaderreen (Counties Roscommon, Sligo, and N.E. Mayo). In the Curlew Mountains the base of these rocks is not exposed; but to the westward, between Ballaghaderreen, it is so, they resting unconformably on metamorphic rocks, either of Cambro-Silurian or Cambrian age, as mentioned in the Paper "On some supposed Cambrian Rocks in the Co. Tyrone and N.E. Mayo."

The mass of the rocks of the Curlew Mountain district belongs to the red arenaceous or "Lower Old Red Sandstone" type, except perhaps in the low country N. W. of Ballaghaderreen, where below and above they are of this type, but between they are of the "argillaceous" type, as more fully mentioned hereafter. All these rocks are evidently detached portions of the basin, other portions of which are found further south-westward, in the neighbourhood of Clew Bay, as in the Croagh Moyle, Mulrany, Clare Island, and Louisburgh districts. The rocks in these places, for the most part, are of the red arenaceous type; although in Clare Island and near Louisburgh there are greater or less thicknesses of red argillaceous rocks. All these rocks from Ballaghaderreen westward lie unconformably on metamorphic rocks, which are either Cambro-Silurian, or passage rocks into the Cambrian ("Arenig group," Upper Cambrian).

Immediately south and south-east of Louisburgh, at Creggaunbaun, and thereabouts, the Silurian rocks are, for the most part, metamorphosed, those that are unaltered belonging to the "argillaceous" type. This is remarkable, because to the south thereof, in the Mweelrea district, the rocks are principally of the red arenaceous type. The Mweelrea district is a portion of the large Silurian area that extends from Loughs Mask and Corrib, on the east, to the Atlantic, on the west, in which the rocks of both types are intermingled. This area occupies portions of S.W. Mayo and N.W. Galway.

In the counties of Cork and Kerry are the rocks belonging to the western extension of Geikie's "Welsh lake basin." Their base is said

not to be exposed in the counties of Cork or Kerry[1]; but in the Commeragh Mountains, Co. Waterford, there are conglomerates and other rocks which the late Mr. John Kelly believed to be of similar age to those of Toormakeady; and if this classification is correct, they must be of Silurian age. To us it seems highly probable that they are the littoral accumulations of the Cork rocks. These Commeragh rocks rest unconformably on Cambro-Silurians.

After this sketch of the Irish Silurians, including under that name the rocks called "Lower Old Red Sandstone," there are more detailed illustrations of the rocks of the Fintona, the Curlew Mountain, and the other, districts.

In the *Fintona district* the general section in a S.S.W. line, from the rocks of the "Pomeroy series" to the flanks of the Altmore hills, gives rocks in the following order:—

Aghafad and Lurgylea Section.

4. Flaggy eurite.
3. Space without any rock exposure.
2. Purplish sandstones, flags, and sandy shales.
1. Greenish and purplish sandstones, flags, and sandy shales.

The eurites (No. 4) resemble compact basic purple felstones, but they are in general full of divisional planes like stratification, which are rarely two feet apart, and usually less than one foot, while in places they are so close together as to give the rock the aspect of a shale; but in the quarry lately opened at the Dungannon Waterworks, in the Altmore river valley, there is a massive eurite, which seems to be at or near one of the centres of eruption.

In the Aghafad and Lurgylea section the rocks east of, or below, the eurite (No. 4) cannot be seen; this space (No. 3) is probably occupied by rocks let down by faults and having a reversed dip, because a mile and a half to the E.S.E., in Glenbeg, eurites and tuffs occur dipping to the N.E. and E.S.E., apparently in the following order:—

Glenbeg Section (Pl. XVI., fig. 3).

6. Yellow tuff.
5. Green, purple, and prismoid eurite (only the weathered outcrop seen).
4. Yellow steatitic tuff.
3. Green and purple tuff.
2. Flaggy eurite.
1. Sandstone.

[1] Mr. M'Henry appears to be of the opinion that some of the rocks in the Co. Kerry classed as Silurian ought more properly to be classed as Cambro-Silurian, they being the equivalents of the rocks of the "Pomeroy series."

These rocks dip away from Altmore; but the eurite (No. 2) is probably the representation of the lower eurite in the Altmore hills, as the section is somewhat similar to that to the westward, as seen at Shane Barnagh's Sentry-box (Pl. XVI., fig. 4).

Shane Barnagh's Sentry-box Section.

6. Very shaly, purplish to greenish, tuffs and tuffose rocks.
5. Shaly, purple eurite.
4. Green tuff; only the weathered outcrop visible.
3. Bedded eurite; beds rarely a foot thick.
2. Conglomerate; only the weathered outcrop seen.
1. Slaty eurite or tuff.

To the S.E., near the Back-bridge, good flags are raised in a portion of No. 3, while to the south thereof, nearer the bridge, the rocks belonging to No. 5 are so very shaly that, if found elsewhere, they would probably be classed as ordinary shales.

The best and most continuous sections are in the country southward of Six-mile-Cross. They, however, are unsatisfactory, on account of the numerous faults. The rocks seem to lie in the following order:—

Section S.E. of Six-mile-Cross.

6. Conglomerates and other arenaceous rocks.
5. Green sandstones and shales, with limestones and calcareous beds.
4. Red arenaceous rocks, with a few green beds and subordinate limestones.
3. Fault of the Glashagh (now Dungannon and Omagh Railway valley).
2. Thick eurite under a limestone (Aghnaglea).
1. Shales and limestone near the Camowen, probably belonging to the "Pomeroy series."

The shales and impure limestones (No. 1) probably belong to an outlying exposure of the "Pomeroy series," as previously suggested. The limestone in No. 2 was formerly extensively quarried, but the quarries are now planted by Lord Belmore.[1] The limestone and associated beds (No. 5) in Tandragee are very similar to those in the country N.W. of Ballaghaderreen, hereafter described, but in the Tandragee beds fossils have not been found as yet.

In the country southward of Six-mile-Cross, and in the neighbour-

[1] It is probable that it was from this locality that the fossils were sent to Griffith of which he said, "I got fossils from that country in rock very like the Toormakeady limestone, but never had time to visit the place myself." See Note in Press, page 500.

hood of the Ballygawley eurite, there is, apparently, a vast thickness of conglomerates. It is probable, however, that the thickness of these is no more than apparent, and that here, as in the similar conglomerates of Toormakeady, Co. Mayo, the conspicuous structural lines are only lines of oblique lamination.

The interbedded eurites, like those in S. W. Mayo and N. W. Galway, have their granitic roots in the older rocks. Thus four miles N. E. of Six-mile-Cross, at the Granagh stream, are rocks in part granite and in part elvan, while south of them is the eurite mentioned in the last section (No. 2), which seems to be on a lower geological horizon than the eurites, &c., of Altmore. Other roots occur in the metamorphic area north and north-west of Six-mile-Cross, and elsewhere. At the mearing of the counties of Tyrone and Fermanagh a mass of shaly eurite was observed and boulders of limestone; but time did not allow of that county being fully examined. Melaphyres, similar to those that occur in the Mayo and Galway Silurians, are found among the rocks of the Fintona district.

To the S.W. of this area special attention was directed to the conglomerate of Lisbellaw, which at that village occurs in mass on the Cambro-Silurians. Half a mile to the W.N.W., however, in the railway cutting, red sandstones are found close to the Cambro-Silurians, while in the stream at the N.E. end of Lough Eyes, two miles from Lisbellaw, the basal rocks are thin conglomerates, sandstones, and shales. Of the interesting blocks in the conglomerate, Mr. Thomas Plunkett, M.R.I.A., states that he "can find no rocks in N.W. Ireland like them, the nearest approach being some of the rocks of West Donegal." It seems probable that as these inliers are granulite, hornstone, quartzite, and other paroptetic rocks, similar to the "baked rocks" of Cambro-Silurian age in other places in Ireland, that they may be derived from a now concealed mass of baked Cambro-Silurians, while the associated inliers of green shale may be the *debris* of the unaltered rocks. A characteristic of the red arenaceous rocks of the Topped Mountain district, to the northward of Lisbellaw, is the presence of innumerable inlying pieces of red, purple, and sometimes green shale. If we may judge from what goes on at the present day, these inliers were small pieces of clay rolled over the sand by the wind, and afterwards flattened out; but where the source of supply was situated it is hard to conjecture.

Of the "Lower Old Red Sandstone" of the *Curlew Mountain district* the most eastward exposure is to the S. E. of Drumshambo, on the eastern side of the Shannon. Both types occur here; those of the "green" series underlying a small thickness of the red; no fossils have been found as yet, although one bed at least looks likely to yield some, if sufficiently searched. It is possible, if not probable, that these rocks are on a much lower geological horizon than those to the west of the Shannon, east and west of Lough Key. The rocks westward of Lough Gara seem to be the oldest in the Curlew Mountain district, the basal beds cropping out in the country between Charles-

town and Ballaghaderreen. The rocks, to a certain extent, belong to both types, as in the Fintona district, to the south-eastward of Six-mile-Cross; but at the same time, except that in a few green and calcareous beds, fossils of typical Silurian (marine) species have been found, all would have been included in the "Lower Old Red Sandstone." These rocks give the following sequence:—

Cashelduff and Ballaghaderreen Section.

5. Eurites, tuffs, and limestones, over	200 feet.
4. Purplish, red and greenish conglomeritic sandstones and sandy shales, about	5000 feet.
3. Green conglomeritic sandstones and shales, with a few thin impure limestones, and some subordinate red shales, about	4000 feet.
2. Red and purplish conglomerates, sandstone, and sandy shales, about	1500 feet.
	10,700 feet.

Unconformability.

1. Metamorphosed Cambro-Silurians or Cambrians.

The rocks in group 2 are exposed in a continuous section in the stream between Cashelduff and Cranmore, there being an unconformability between them and the underlying metamorphic rocks; they may possibly be a little thicker than represented, as a fault, with a downthrow to the southward, crosses the section, and may conceal some of the beds. The rocks in group 3 are not as well exposed, while the thicknesses of groups 4 and 5 had to be estimated. A little above the base of group 3, in the Cashelduff stream, are two fossiliferous bastard limestones; the fossils being principally of Upper Llandovery types, although a few are of Caradoc-Bala species (see Mr. Baily's list). To the west is Griffith's fossil locality, in the boundary of Glenmullynamaher and Uggool, where the fossils are principally of Wenlock types, although in beds below and above (Cloonnamna) this bastard limestone, they are of Upper Llandovery species; showing here also, as elsewhere in Ireland, the mixing together of species which in Wales are characterisic of distinct groups of rock.

The rocks in groups 2 and 4 are so nearly allied that they would not have been separated but for the intervening fossiliferous strata. Furthermore, the intervening rocks (group 3) are not so very unlike "Lower Old Red Sandstone," except as to colour, and the few calcareous and shale inliers; they being principally pebbly sandstones, with the inlying patches of shales so characteristic of the rocks of the Topped Mountain, Co. Fermanagh; they ought not, therefore, to be considered a separate group, but only a subordinate portion of a group.

A very similar change of colour takes place in the section of the Silurian rocks of Dingle, Co. Kerry (see Pl. XVI). The rocks of group 4 are best exposed in the neighbourhood of Lough Gara: but no satisfactory section of group 5 can be seen, although enough is exposed to suggest that they lie in the trough of a shallow synclinal curve, and that they are of greater thicknesses in some places: they seem to be associated with subordinate beds of impure limestone, because, although the latter rock was not found *in situ* except at Lough Key, yet elsewhere fragments occur associated with the eurites.

From the sections, it may be suggested that the rocks of the "Red arenaceous" type were either littoral accumulations, or depositions in shallow water; while the green beds seem to have been laid down in deeper water, which afterwards became shallow. In two places, viz., at Doon, on the west of Lough Key, and at Moy Gara, to the N. W. of Lough Gara, tracks, perhaps crustacean, very similar to those found at the Valencia Lighthouse, Co. Kerry, were observed.

In the Curlew Mountain district, as well as in the Fintona district, there are remarkable peculiarities in the feldspathic rocks. As mentioned already, those of Fintona have a thin-bedded structure, which looks like the stratification of sedimentary rocks or tuff, although they appear to be eruptive; here, however, their tuff nature is undeniable. To this subject attention has already been directed by Jukes and Foot (*Journ. Roy. Geol. Soc., Ireland*, vol. i., p. 247); but those observers appeared to be of the opinion that some of these rocks in the country between Loughs Gara and Key might be classed as normal eruptive rocks. In this Report it is pointed out that, to the westward, between Charlestown and Ballaghaderreen, there are roots of the eurites, elvans, and porphyries, occurring in the metamorphic rocks, while in the Lower Old Red Sandstone westward and northward of Ballaghaderreen there are bedded eurites and tuffs; but eastward in the Curlew Mountains the fragmentary and bedded characters are very decided, the euritoid rocks being breccias, grits, sandstones, and finely-laminated shales, all apparently having been re-arranged and deposited in water. From this it is suggested that the vent of eruption was to the westward; a characteristic of the vulcanicity being great discharges of tuff, or such-like mechanical products, which were subsequently re-arranged and deposited by water over a large area. This eruption must have been considerable, and for some time continuous, as otherwise the arenaceous rocks would have been interstratified with the tuffs, which does not seem to be the case. The isolated masses of these tuffose rocks on the Curlew Mountains are portions of the massive beds, separated and detached by breaks and denudation. The suggestion now offered to account for the phenomena just described accords with that proposed by Messrs. Du Noyer and Foot, in explanation of the similar phenomena to be observed in the rocks at Glenflesk, Co. Kerry.

At Doon, on the west of Lough Key, melaphyres similar to those of N. W. Galway occur associated with the euritoid rocks.

In continuation of the account of the "Lower Old Red Sandstone" basin on the westward, short descriptions of the Silurians of S. W. Mayo, N. W. Galway, and Kerry, appeared in the original Report. In the *Croagh Moyle district*, the "Lower Old Red Sandstone" consists principally of conglomerates, which lie unconformably on Cambro-Silurians or Cambrians (*Arenig rocks*). In places, under the conglomerates, are red sandy shales and sandstones; while very similar rocks occur in the country to the N. W. No eruptive rocks occur in them; but in places at their margin are limestones in the underlying rocks,[1] which are somewhat similar to the limestones, the associates of the eurites in the Fintona district, to the N. E., and in the Toormakeady district, a little to the southward.

Adjoining Clew Bay, near Mulrany, in Clare Island, and near Louisburgh, the rocks are somewhat similar to those of Croagh Moyle, except that red argillaceous rocks are more or less developed. In the north portion of the Louisburgh district these argillaceous rocks occur in mass; while in the south portion they are interstratified with the arenaceous. The Louisburgh beds constitute perhaps the latest division of the "Lower Old Red Sandstone" in Mayo, as they lie against metamorphic rocks (having been brought into that position apparently by a fault), an unaltered portion of which, at Creggaunbaun, contains fossils principally of Wenlock types. The relative positions of the rocks of Louisburgh, those of Creggaunbaun, and those further south in Mweelrea, are shown in the horizontal section, Plate XVI., fig. 5.

In the country to the south of the Croagh Moyle and Creggaunbaun rocks, and separated from these by Cambro-Silurian rocks, is the long narrow tract, extending from Lough Mask by the north of Killary Bay to the Atlantic, including the *Toormakeady*, *Formnamore*, and *Mweelrea districts*. Here, on the eastward (Toormakeady), there are massive conglomerates of the "Lower Old Red Sandstone" type, under which are fossiliferous limestones and shales. The conglomerates to the west of these in Formnamore merge into thin-bedded purple and green grits and shales; while still further westward, in Mweelrea, the rocks of the two types are more or less intermingled. That these different rocks are on one geological horizon seems proved, as below them are the continuous interbedded eurites and tuffs, which to the eastward are associated with the fossiliferous Toormakeady limestones and tuffs. The fossils of the latter are principally of Caradoc-Bala types, and similar fossils occur in green shales above the eurites to the westward in the Mweelrea district. This narrow area is remarkable; as there are not only rocks of the "Lower Old Red Sandstone" type and those of the "grey and green" series on the same geological horizon, but the fossils therein are principally those characteristic of the Welsh Caradoc-Bala rocks (Cambro-Silurian).

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[1] Symes has stated that these calcareous rocks may be of Carboniferous age, being due to infiltration.

This tract is bounded on the southward by a fault with a downthrow to the south; south of which is a second long narrow tract, extending from Loughs Mask and Corrib to the Atlantic, on the south of Killary Bay. In this area the rocks are, for the most part, of the "grey and green type"; but in places, as subordinate groups, sometimes coming in quite suddenly, and usually below, are rocks of the "Lower Old Red Sandstone" type; but the most conspicuous are the "Salrock slates," above, and probably at or near the same geological horizon as the "Louisburgh beds." A peculiarity connected with the "Salrock slates" is that, although the latest Silurian group in the county of Galway, the characteristic fossil is pronounced by Davidson to be of an English Upper Llandovery type. To the west of this tract, above the eurites, which are on the same geological horizon as those just mentioned as occurring at the base of the Mweelrea and Toormakeady rocks, there is a zone carrying Caradoc-Bala fossils; while below this zone the fossils are of species characteristic of the Upper Llandovery and Wenlock; while to the eastward, on this lower horizon, in the neighbourhood of Loughs Mask and Corrib, the fossils have been pronounced by Salter, Harkness, King and Baily, to be of types similar to the English Wenlock and Ludlow.

As the bedded eurites with their associated tuffs occur both north and south of the great fault that separates this tract from that to the north, it would appear that, although the rocks in the two areas were being accumulated at the same time, yet it was under very different circumstances, as to the depth of the sea and the animal life in the different portions of it. The changes in passing from north to south are very sudden, while those from west to east are more gradual: this is even more striking if we also take in the rocks farther northward. If a line be drawn from Croagh Moyle to Lough Corrib, the rocks at the northern end are the Croagh Moyle conglomerates, next are the Toormakeady conglomerates, with the fossiliferous limestones at their base (Caradoc-Bala fossils), and immediately south of them are rocks containing Wenlock and Ludlow fossils. Along a line from Mulrany, on the north side of Clew Bay, to the south side of the mouth of Killary Bay, the rocks exhibit even greater peculiarities, as shown in the following Table:—

Mulrany.—Arenaceous rocks principally.
Louisburgh (*north*).—Red argillaceous shales.
Louisburgh (*south*).—Red argillaceous and arenaceous rocks interstratified.
Creggaunbaun.—Green and grey fossiliferous rocks—(Wenlock type).
Mweelrea.—Red arenaceous and green argillaceous—the latter fossiliferous (Caradoc-Bala types).

GREAT EAST AND WEST FAULT.

Salrock.—Red slates (Upper Llandovery fossils).
Upper Lough Muck Beds.—Llandovery and Wenlock fossils).
Lower Lough Muck Beds.—(Caradoc-Bala fossils).
Gowlaun Beds.—(Llandovery and Wenlock fossils).

As to the Dingle promontory, Co. Kerry, although outside the province of the inquiry, it was pointed out that the rocks were both of the "grey and green" and of the "Lower Old Red Sandstone" types, and that in the *Anascaul beds* there are fossils of Caradoc-Bala species.[1] Of the other groups, the *Smerwick beds,* which are stratigraphically the oldest of the continuous sequence, are of "Lower Old Red Sandstone" type, and unfossiliferous; while above them are the grey and green fossiliferous *Ferriter's Cove series,* and, higher up, the *Croagh Marhin series,* which are a combination of both types; some beds being light-coloured and fossiliferous, the fossils being for the most part of Ludlow species, while over all come the typical reddish arenaceous Dingle beds.

A *résumé* in the original Report gave the relations between the different areas of the Silurian and underlying rocks.

AN EPITOME OF THE RESULTS OF THE INQUIRY.

Relations between the Silurian ("Lower Old Red Sandstone") *and the underlying and overlying Strata.*

Pomeroy.—In this immediate neighbourhood the rocks of the "Red arenaceous" type seem to lie unconformably on the rocks of the "Pomeroy series" (Cambro-Silurian), which they seem to overlap; north-westward, the rocks adjoining them are metamorphosed Cambrians; and southward they are overlain unconformably by Carboniferous sandstones.

Six-mile-Cross.—To the N. E. of this village, about a mile N. W. of Carrickmore, the Lower Old Red Sandstone lies against granite rocks of Silurian age; while about two miles S. W. of Carrickmore, in the valley of the Camowen river, there appears to be under them an outlying mass of rocks of the "Pomeroy series." Some of these "Lower Old Red Sandstones" are of the "Red arenaceous" type, in which there are subordinate limestones and greater or less thick-

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[1] Jukes and Du Noyer have classed these beds as Silurians: but after more recent research we are informed by Mr. McHenry that he suspects that they ought to be classed as Cambro-Silurians; this was also Griffith's classification, but solely on fossil evidence.

nesses of the rocks of the "grey and green" type. Some of the limestones are probably fossiliferous. In the country N. W. of Six-mile-Cross the Silurians appear to lie directly on the metamorphosed Cambrians.

Lisbellaw.—Here rocks of the "Red arenaceous" type lie unconformably on Cambro-Silurians, while they are overlain unconformably by Carboniferous rocks.

Drumshambo.—The Silurian rocks near this place are of both the "Red arenaceous" and the "grey and green" types. They probably lie, as at Lisbellaw, on Cambro-Silurian, but their base is not exposed. They are overlain unconformably by Carboniferous rocks.

Curlew Mountains.—The rocks here appear to be some of the latest Silurians in N. E. Connaught, and to be on a higher geological horizon than the rocks of Drumshambo; also than those to the westward, N. W. of Ballaghaderreen. They are principally of the "Red arenaceous" type, although to the N. W. of Lough Key the top of the "grey and green" rocks is seen. They are overlain unconformably by the Carboniferous rocks.

Ballaghaderreen.—To the westward, and north-westward of Ballaghaderreen, rocks of the "Red arenaceous" type lie unconformably on metamorphosed rocks, which may be of either Cambrian or Cambro-Silurian age. In the rocks of the "Red arenaceous" type is a mass of grey and green rocks, containing fossils of Silurian and Caradoc-Bala types. The rocks of the "grey and green" type evidently constitute only an inlier in the others, similar to those near Six-mile-Cross; except that in the last, fossils have not as yet been found. The Silurians are overlain unconformably by Carboniferous rocks.

Croagh Moyle.—Here the rocks all belong to the "Red arenaceous" type; being principally conglomerates, although in one place at least there is below them a considerable thickness of sandstone and sandy shales. They lie unconformably on metamorphosed Cambrians or Cambro-Silurians, while they are overlain unconformably by Carboniferous rocks.

Mulrany.—Here are conglomerates, sandstones, and shales belonging to the "Red arenaceous" type, lying unconformably on metamorphosed Cambro-Silurians, and overlain unconformably by Carboniferous rocks.

Clare Island.—Although the rocks here belong to the "Red arenaceous" series, there is in them a considerable thickness of red slates or shales. They lie unconformably on metamorphosed Cambro-Silurians.

Louisburgh.—Here, as in Clare Island, red slates and shales appear in the rocks of the "Red arenaceous" type, especially in the northern portion of the area, where they are of considerable thickness; while in the southern part they are interstratified with sandstone and conglomeritic rocks. The rocks of part of this area lie unconformably on metamorphosed Cambro-Silurians, while the rest are brought down by a fault against metamorphosed Silurians.

Creggaunbaun.—In the greater part of this area the rocks are metamorphosed. Those that are unaltered are of the "grey and green" type, and yield fossils of Wenlock and Upper Llandovery types. They lie unconformably partly on metamorphosed and partly on unaltered Cambro-Silurians.

Mweelrea Mountains.—The rocks here are partly of the "Red arenaceous" type and partly of the "grey and green" type: the two types in places are intermingled. In some of the grey and green beds there are fossils principally of the Caradoc-Bala species. They lie unconformably on metamorphosed and unaltered Cambro-Silurians.

Formnamore Mountains.—These rocks, although on the same geological horizon as those of the Mweelrea Mountains, are, for the most part, of the "grey and green" type, but no fossils have been found in them. They lie unconformably on metamorphosed Cambro-Silurians, and are capped by Carboniferous rocks.

Toormakeady Mountains.—Here a second change takes place; the rocks, although a continuation of the last, being nearly altogether massive red conglomerates; but at their base are limestones and tuffs, carrying fossils of Caradoc-Bala types. They lie unconformably on metamorphosed and unaltered Cambro-Silurians; while, like the rocks of the Formnamore Mountains, the Carboniferous rocks lie unconformably on them.

Tract of Country between Cong, Lough Corrib, and the Culfin, on the Atlantic.—The rocks here are separated from those of Mweelrea, Formnamore, and Toormakeady, by a great nearly E. and W. fault, with a downthrow to the southwards. They are nearly altogether of the "grey and green" type, but with them are associated remarkable subordinate sets of beds of the "red arenaceous" type. The uppermost beds, "Salrock slates," belong to the latter, and have, as their characteristic fossil, one of an Upper Llandovery type; while lower down various types of fossils are intermingled—one zone carrying fossils of Caradoc-Bala species. These rocks lie unconformably on metamorphosed rocks of Cambro-Silurian and Cambrian ages, while they are covered unconformably by the Carboniferous rocks.

Dingle Promontory.—The rocks (*Anascaul beds*) that are supposed to be the oldest in this district contain Caradoc-Bala species. Jukes and Du Noyer classed them as Silurians, while Griffith and M^{c}Henry would put them among the Cambro-Silurians. Of the rocks forming a continuous sequence, the lowest (*Smerwick beds*) and the highest (*Dingle beds*) are of the "red arenaceous" type; the rocks in the intermediate groups are of mixed types, the "grey and green" type predominating. The base of the rocks of the sequence is not seen; while on the Dingle beds the Carboniferous rocks lie unconformably.

Glengariff Grits.—These rocks are principally of the "red arenaceous" type; their base is not exposed; while on them the Carboniferous rocks rest conformably in the country to the southward (West

Cork), and unconformably in the country to the N. E. (south-east Kerry and north-east Cork).

Commeraghs (Waterford).—In these mountains are conglomerates very similar to those of Toormakeady and Croagh Moyle, which were supposed by Kelly to be of similar age. They are possibly the littoral accumulations of the Silurians of West Cork (Glengariff grits). They rest unconformably on the unaltered Cambro-Silurians, while they seem to be covered unconformably by rocks of Carboniferous age.

SILURIAN EURITES.

These rocks and their associates are characteristic of the "Lower Old Red Sandstone," not only of Ireland, but also of Scotland. The Irish rocks are not all on the same geological horizon. It may be possible that they are the results of two periods of active vulcanicity, and, for the present classification, it may be supposed such was the case, and that they belong to two different zones.

Upper Eurite Zone.

Fintona District.—Eurites, tuffs, and calcareous rocks, at Altmore and N.E. of Fintona. The eurites and limestones eastward of Six-mile-Cross seem to be older than, while the eurites near Ballygawley seem to be of the same age as, those eastward of Six-mile-Cross.

Curlew Mountain District.—Tuffs and calcareous rocks of the country between Loughs Key and Gara. Near Ballaghaderreen, eurites, tuffs, and limestone.

North-west Galway.—The bed of eurite in the "Salrock slates" of the hills south of Leenaun; limestones at Dernasliggaun and Rossroe; and the newer eurites in the Kilbride promontory (Lough Mask).

West Kerry.—Eurites and tuffs, Valencia Harbour.

East Kerry.—Eurites and tuffs of Glenflesk, Lough Gitane, and the Horse's Glen (Mangerton).

Lower Eurite Zone.

Croagh Moyle District.—The limestones at the base of the Silurians.

Toormakeady District.—Eurites, tuffs, and limestones, at the base of the conglomerates.

Formnamore.—Eurites at the base of the group.

Loughnafooey.—Eurites and limestone in the vicinity of Loughnafooey; oldest eurites and tuff of the Kilbride promontory (Lough Mask); eurites of Rinavore (Maum Valley).

Mweelrea District,—Eurites at the base of the Silurians.

Culfin.—Eurites of Benchoona and of the hills to the eastward.

Dingle Promontory.—Eurites and tuffs in the "Ferriter's Cove series."

NOTE ADDED IN THE PRESS.

From Glashagh, the valley adjoining Lord Belmore's quarry, Mr. Thomas Plunkett, M R.I.A., has sent me a piece of a fossiliferous boulder of a greenish argillaceous rock. This rock is very similar to some of the rocks of the "Pomeroy series," and contains fossils common therein; but it is also similar to some of the green argillaceous rocks of Tanderagee. In these, however, no fossils have been found as yet. The principal fossil, *Leptæna serica*, is one of the characteristic fossils of the Toormakeady Silurians, and therefore it may possibly occur in the Tanderagee "grey and green beds." The boulder could scarcely have come from the Pomeroy area, as the driftage from that was towards the south; but, as I have already suggested, there may possibly be an outlying exposure of these rocks to the north of this place; while it is also possible that the "Glashagh fault" may bring up the rocks of the "Pomeroy series" under the drift of the valley.

EXPLANATION OF PLATES.

Plate XVI., Fig. 1.—Map of the Pomeroy area, showing the probable extent of the rocks of the "Pomeroy series" and some of the eruptive rocks of the Altmore district.

,, Fig. 2.—Aghafad section, showing the probable unconformability between the rocks of the "Pomeroy series" and the "Lower Old Red Sandstone."

,, Fig. 3.—Glenbeg section, showing the reversed position of the eurites and tuffs.

,, Fig. 4.—Shane Barnagh's Sentry-box, section of the eurites, tuffs, and associated rocks.

,, Fig. 5.—Sections showing the relations between the Silurian rocks of Louisburgh, Creggaunbaun, Mweelrea, Salrock, and Lough Muck.

Plate XVII.—Longitudinal section indicating the original position of the rocks in the Silurian basin between Clare Island, Co. Mayo, and Cushendun, Co. Antrim. The probable outline of the floor of the sea is indicated, while the faults that have since shifted it are left out.

,, Sections showing the relations between the beds in the Mweelrea and Partry Mountains with those to the north in Croagh Moyle.

,, Three series of vertical sections: one showing the sections at the principal points in the main longitudinal sections; another of the principal sections in the longitudinal section from Mweelrea to Croagh Moyle; and the third, the sections along the cross sections from Culfin to Louisburgh (fig. 5, Plate XVI.).

Fig. I.

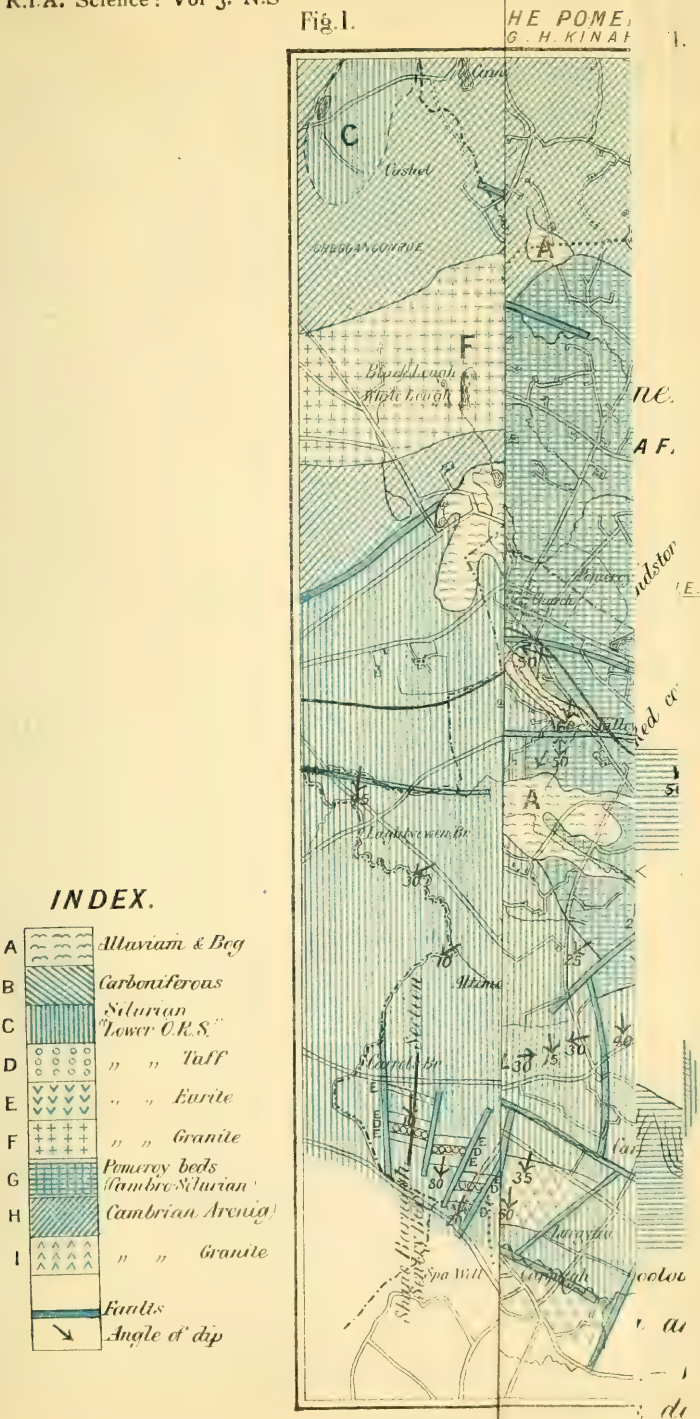
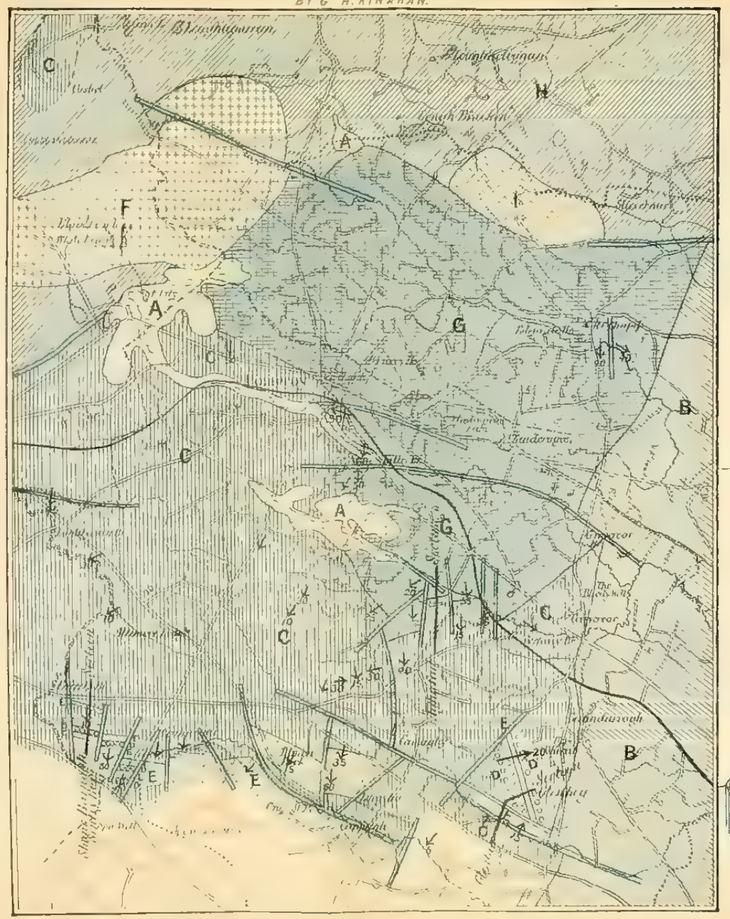
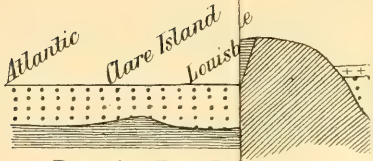
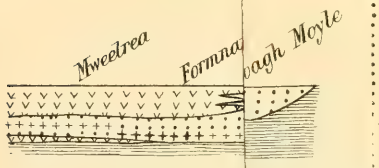
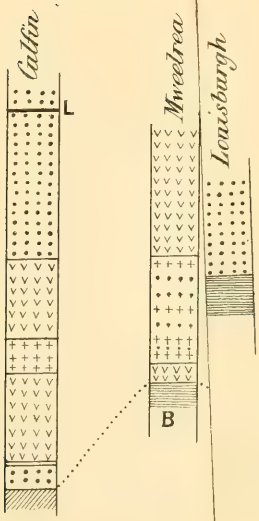

INDEX.
A Alluvium & Bog
B Carboniferous
C Silurian "Lower O.R.S."
D " " Tuff
E " " Eurite
F " " Granite
G Pomeroy beds (Cambro-Silurian)
H Cambrian Arenaig
I " " Granite
Faults
Angle of dip

Fig. 1. MAP OF THE POMEROY SERIES.
BY G. H. KINAHAN.


Ballynakilly
Ballynagarran
Tullyvar
Tullyhogue
Tullyhogue Fort
Ballyreagh
Ballyreagh Mt.
Ballyreagh Lough
Ballyreagh Glebe
Ballyreagh Ho.
Ballyreagh Cross Roads
Ballyreagh Bridge
Ballyreagh Mill
Ballyreagh Ho


Atlantic
Clare Island
Longitudinal


Mweelrea
W & E. Section from


Caltin
L
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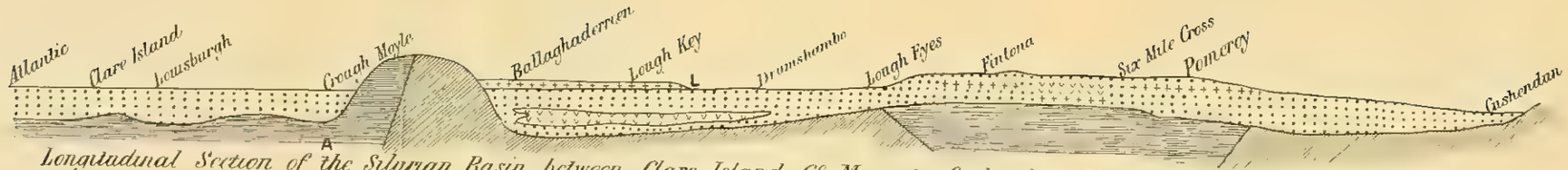
Louisburgh
B

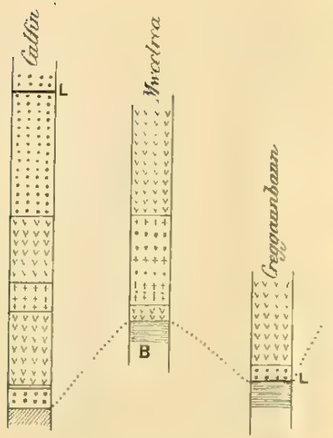
N & S. from th



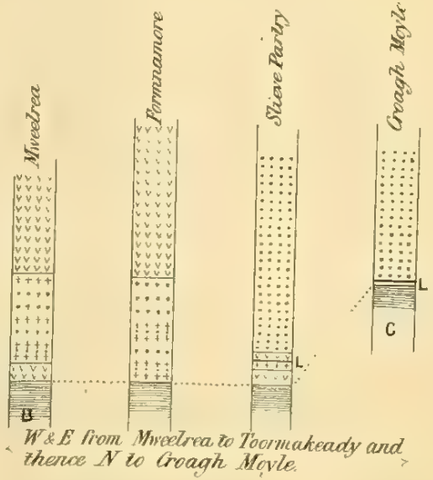
Longitudinal Section of the Silurian Basin between Clare Island Co Mayo to Cushendan Co Antrim without the great fault lines

Scale, Horizontal. 20 Miles to One Inch. Vertical 40 000 Fe to One Inch

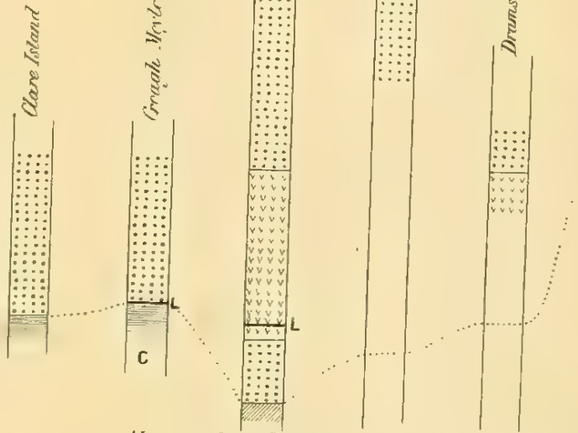
W & E Section from Mweelrea to Toormakeady thence N to Croagh Moyle



N & S. from the Culfin to Clew Bay.

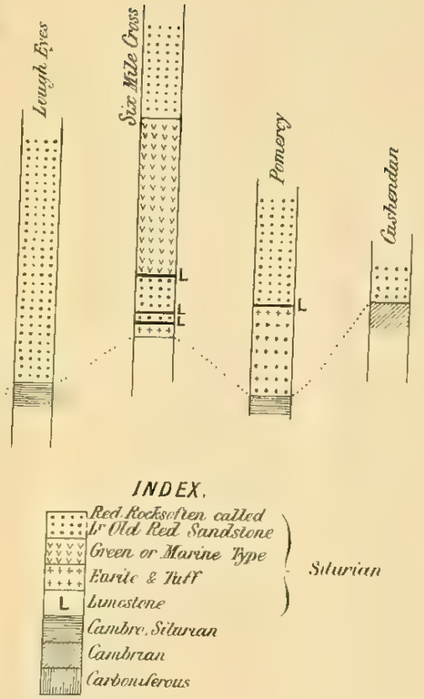


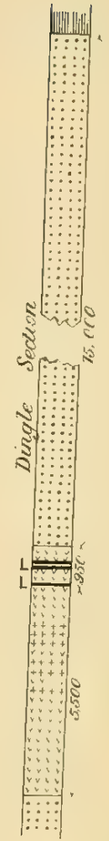
W & E from Mweelrea to Toormakeady and thence N to Croagh Moyle.



Along the Basin from Clare Island to Cushendun.

Scale of Vertical Sections - 4000 Feet to One Inch.





Forster & Co Lith, Dublin

LXXI.—PRELIMINARY REPORT ON THE EMBRYOLOGY OF THE MAMMALIAN MUSCULAR SYSTEM.

By B. C. A. WINDLE, B.A.

[Read, June 27, 1881.]

THE subject of the development of the muscular system is one which has up to the present time received very little attention. The literature on the subject is extremely scanty, consisting only of a few Papers by Georg Ruge, of Heidelberg, and Cunningham, of Edinburgh.

In carrying out the investigations, for which I received last year a grant from the Royal Irish Academy, I have made a large number of microscopic sections of the manus and pedes of several puppies (fœtal) of the tenth day. I have also made sections of the manus and pedes of human embryoes of various ages. In this preliminary Report I purpose giving a short description of the condition observed in the manus and pes of the fœtal puppy of ten days.

PES.—Commencing at the distal extremity, the tendons of the flexor brevis digitorum (perforatus) are seen attached to the three central digits, and perforated by the tendons of the flexor longus digitorum (perforans). The bones at this point of section are of a somewhat rounded shape, flattened on their plantar aspect.

Approaching nearer to the proximal extremity, the point of section passes through the four digits, to which the same flexor tendons are attached; whilst two slips of tendon from the extensor longus digitorum or brevis are to be observed on the dorsum of each of the three outer toes.

A section through the centre of the metacarpal bones presents the following points for observation :—

Bones.—There is much less space between the three middle metacarpal than between these and the first and fifth. The latter two also are of a much more regularly circular shape than the others.

Tendons.—On the dorsal aspect slips connecting the extensor tendons with the bones.

On the plantar aspect the tendons of the flexor longus digitorum.

Muscles.—The interossei are all on the plantar aspect of the foot, and are of the normal number and distribution. The fibres of the flexor brevis digitorum are visible, cut transversely. The flexor brevis hallucis and flexor brevis minimi digiti are also to be seen.

A section through the proximal extremities of the metacarpals shows—

Bones.—The three middle metatarsals are very close to one another. The first and fifth are closer to the remaining ones than in the previous section. The shape of the first and fifth, instead of being round, is now spade-like, or, more strictly speaking, like the ace of spades in shape. Cartilages, subsequently to ossify into sesamoid

bones in the tendons of the flexors, are observable on the plantar aspect of these two metacarpals.

Tendons.—Those of the long flexors are to be seen.

Muscles.—Interossei occupying the same positions as in the previous section. Four lumbricales are also present, situated near the tendons of the flexor longus digitorum.

Manus.—Sections passing through the distal extremity of the manus present a very close resemblance to those taken from the pes. The tendons of the perforating and perforated muscles lie in the same position in both.

A section taken through the first phalangeal joint shows the cartilages, which, by subsequent ossification, become sesamoid bones in the flexor tendons.

The most instructive section of the manus is one taken through the centre of the metacarpus. Such a section presents the following objects for observation:—

Bones.—There is no space left between the third and fourth metacarpals, but a small one between the second and third and first and second, and for the most between the fourth and fifth. The three central metacarpals are of a somewhat oval shape. The fifth is more nearly circular, while the first is of this shape (⌒).

Tendons.—The slips attaching the extensor tendons to the bones are visible, as are also the tendons of the perforating and perforated flexors.

Muscles.—The following are observable:—Flexor brevis pollicis, flexor brevis minimi digiti. Three lumbricales. The normal interossei are present, but there is an extra interosseous muscle in the interspace between the second and third metacarpal bones. This also differs from the others in its situation, the normal muscles lying to the palmar aspect of the metacarpals, and the extra one between the two before mentioned. It is interesting, as pointing to a possible original symmetry of the interossei in point of numbers; but before laying any stress on this point, I am anxious to discover whether a similar arrangement obtains in other canine manus.

I hope soon to be in a position to lay before the Academy a more extended Report of my investigations on the human manus, which I am now carrying on.

Having lately obtained a large supply of materials, in the shape of human fœtus, I hope to be able to make a tolerably complete examination of them.

In conclusion, I desire to take this opportunity of thanking Dr. Macalister for materials and much kind assistance.

LXXII. — On a Relation to be established between Coast-line Directions represented by Great Circles on the Globe and certain Localities in Europe marked by frequency of Earthquakes. By Joseph P. O'Reilly, C.E., Professor of Mining and Mineralogy, Royal College of Science, Dublin.

[Read, November 14, 1881.]

For the student of Geology no phenomena of Nature present a wider, more interesting, or more important field of study than Earthquakes. So sudden, so terrible in their effects, so difficult to observe, so mysterious in their causes (even in the present advanced state of knowledge), and therefore so insufficiently studied, every branch of science can find in them matter for observation and study second to none in importance. It might seem, therefore, that a complete, continuous, and systematic record of such events would be deemed indispensable for the progress of the natural sciences; and such a record we possess in Mallet's Report and Catalogue of Earthquakes up to 1850, published by the British Association, but for the subsequent years it is to be regretted that we have no continuous catalogue in English, such as those of Professors Perrey and Fuchs in France and Germany.

That this is really a want must be evident from the interest excited by the increasing frequency and intensity of earthquakes in Central Europe, by the manifest desire to collect more precise and extended information as regards their occurrence, and by the admitted insufficiency of the theoretical views in vogue as regards their causes.

The records of Professors Perrey and Fuchs, with difficulty accessible in Great Britain, are yet of the greatest value, and their examination suggests the possibility and the desirability of bringing into more intimate relationship earthquakes, as phenomena, which are apparently quite independent, and have up to the present been only brought into connexion from the point of view of contemporaneity.

Yet the dependency existing between volcanic action and earthquakes is fully admitted; moreover, there is recognised a well-established connexion between volcanoes and great lines of jointing, more especially sea coast-lines. It is therefore reasonable to assume that a similar connexion may be found to exist between these and earthquakes—that is to say, sea coast directions and lines of main jointing being recognised as the loci of volcanic actions, so evidently connected with earthquakes, should there not, consequently, exist some relation between these same directions, as representing lines of main jointing and localities markedly affected by earthquakes, far apart though they may be geographically?

In the present memoir I endeavour to establish such a connexion, parting from the Theory of Coast-lines Correlation, submitted to the British Association in 1878 (Dublin), and subsequently published by the Royal Irish Academy in its *Transactions* (November, 1879). In that

memoir[1] I endeavoured to show that the direction of coast-lines in general is mainly due to jointing; that this must be dependent on the mineralogical constitution of the rock or rocks in which it is developed; that this constitution, variable at surface, must change in depth; and in so far as we have any knowledge of it for great depths, may be presumed to be that of the trap-rocks or basalts; that these, when in great masses, frequently present a columnar structure, acquired by contraction; that the predominating angles of the prisms formed are, as observed at the Giant's Causeway, of 110°, 70°, 40°, and angles resulting from the combination of these. I further argued that secular contraction is admittedly going on in the crust and at the surface of the earth, but only locally, and therefore unequally; that there are being formed continuously in the earth's crust points of maximum tension; that when rupture and consequent local contraction take place, there are produced planes of rupture or joints, which necessarily divide off and limit a certain extent of the earth's crust, and give rise to polygonal forms at the surface of the globe; that these planes or joints being developed in massive rock, presumably of the nature of basalts, and of very great thickness and extent, give rise to polygonal or prismatic forms, presenting angles such as those observed in basalts; that by reason of the predominance of certain angles these must repeat themselves, and give rise to directions of planes of jointing which at intervals are similar; and consequently, that prolonging on the earth's surface a system of jointing along which contraction towards the centre has taken place, this system, marked by its direction, should reoccur at intervals, and show a connexion or correlation with other directions through the intermediary of the predominating angles already mentioned.

This theory was supported by examples, and subsequently by the determination and comparison of the systems of jointing observable about the Bay of Dublin, which I showed to have manifest relations with the directions of the neighbouring coast-lines, in accordance with the theory submitted.[2]

Such a theory, however, requires repeated and very direct proofs before it can claim acceptance. If well founded, it should admit of being pushed to its logical consequences, and such I take to be the connexion which I propose to establish between coast-line directions (or their correlated lines and parallels) and localities noted for their earthquakes.

As a matter of fact all earthquakes, whatever their origin, must bring into play the systems of fissuring and jointing which have existed in the locality, tending, however, to modify them and to increase their extent and number.

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[1] "On the Prismatic Forms of a Group of Basalts, Giant's Causeway." (Roy. Irish Acad. *Transactions*, vol. xxvi., part 22, Nov. 1879.)

[2] "On the Directions of the Main Lines of Jointing observable in the Rocks about the Bay of Dublin, and their Relations with the adjacent Coast-lines." (Roy. Irish Acad. *Proceedings*, vol iii., ser. ii., No. 5, Dec. 1880.)

Now, assuming as admitted, Firstly, the connexion between volcanic action and earthquakes; Secondly, the connexion between volcanic action and coast-line directions; and Thirdly, the connexion between coast-line directions and main systems of jointing, there should be a connexion existing between these coast-line directions and localities wherein earthquake action manifests itself.

If, therefore, the earthquake records for a series of years be taken, and the localities mentioned be noted on a map; if, furthermore, the coast-line directions traced by me *à priori* on the globe be also laid down on this map, there should (if my theory be well founded) be apparent some relation between the earthquake localities and these directions or their correlated lines.

It is this test, applied to the map of Europe, which I now submit for consideration, carried out by marking the earthquake localities noted in the records of Mallet, Perrey, and Fuchs down to 1880.

In thus marking the localities mentioned, I was unable to distinguish between intensity and frequency of occurrence, except by hatching districts over which shocks have extended, and rehatching or cross-hatching, to mark the reoccurrence of the earthquake under the same conditions. For single localities, however, a simple round or small circle in red indicates that they have been cited as having suffered at least one shock.

No such map has been before prepared, and the present one must be judged rather as an essay than as a complete work. If intensity and frequency could be represented on such a map, very interesting relations would certainly be established thereby. If, moreover, such mapping could be done on a globe, still more remarkable results might be expected to follow.

An examination of the map shows that as the localities are multiplied, so does their tendency to develop into certain lines become more marked; and considering, on the one hand, the meagreness and incompleteness of these records down to the middle of the last century, or commencement of the present, and on the other the shortness of historic time as regards the development of geognostical phenomena, the results manifested by the map must be considered as distinctly pointing to a law of connexion between coast-line directions and certain earthquake districts in Europe.

Of the localities lying in Europe and around the basin of the Mediterranean, which have been and continue to be marked by frequent and violent earthquakes, the following are the principal:—

Italy and Sicily.

The Adriatic coast-lines.

Greece and the adjacent islands.

The triangular space bounded on the west by the Rhone, on the south-east by the Mediterranean coast-line from Marseilles to Genoa and the prolongation thereof from Genoa to Trieste, and on the north-east by a line extending from the Vosges to the neighbourhood of

Trieste. (This triangular space takes in Switzerland and part of the Tyrol.)

The Rhine district, extending from the confines of Baden and Switzerland to Holland in a direction nearly north and south, and presenting about one hundred miles in breadth from west to east.

The Saxony district, more circumscribed, but perfectly well marked.

Various districts in France, particularly the line of the Pyrenees.

Great Britain.

The west coast of Portugal.

The south-east coast of Spain.

Sweden and Norway.

Outside Europe proper, and in connexion with the Mediterranean nd Black Seas :—

Asia Minor, especially the west coast and Sea of Marmora.

The north coast of Africa.

The Syrian coast.

The line of the Caucasus.

As explained in the memoir "On the Prismatic Forms of a Group of Basalts," I traced on the globe sixty-seven coast-line great circles, correlated by certain angular relations, and of these great circles the following traverse Europe and the adjacent continents :—

No.

2. East Cape Madagascar.
3. West coast of Read Sea.
4. East coast of Red Sea.
5. Coast of Syria.
7. West coast of Morocco.
12. Southern boundary of the tertiary formation of the United States.
13. East coast of South America.
14. North coast of Africa.
15. West coast of Portugal.
16. East coast of England.
23. Caucasus great circle.
24. South-east coast of Africa (Sofala coast).
28. Axis of Sumatra.
32. North-east coast of Persian Gulf.
50. Promontory of New Ulster.
51. East coast of Sweden.
53. East coast of New Zealand.
52. West coast of Sweden.
66. South-west coast of Australia.

I have now to show in what relation these lines stand.

First, with the localities in Europe marked by earthquake action; and secondly, with similar localities outside Europe.

In discussing the first point I shall confine my observations to those lines which the method employed in recording the earthquakes on the map has brought out prominently and distinctly, leaving aside for the present the less well-marked lines and less clearly-defined districts.

The following may be pointed out as such well-marked lines:—

I.—*The Boundary Line of the Tertiary Formation of the Valley of the Po.*—This line meets the coast-line direction No. 13 (east coast of South America) at Novara, making with it an angle of 70°. It is very remarkable by reason of the frequency of earthquakes along its direction. On it are situated Pavia, Piacenza, Parma, Reggio, Modena, Bologna, Imola, Faenza, Forli, Rimini, Ancona—all frequently cited on account of their earthquakes, the shocks either having been noted in a single locality, or at several localities along the line.

Its prolongations north-west and south-east, within the limits of Europe and the coast of Syria, pass through many localities remarkable for the frequency and intensity of their earthquakes. Thus, on the north-west it traverses Mount St. Bernard, the Rhone at Tournus, the district about Tours, and cuts the coast-line of Finisterre at Landernau, an earthquake point. Towards the south-east it practically represents the axis of the Adriatic, cuts the Albanian coast at Durazzo, the Thessalian coast at Volo (both well known by reason of their frequent earthquakes), traverses the Sporades, cuts Rhodes at its northern point, and the Syrian coast about Ascalon, crossing the Dead Sea at its southern extremity.

The coast-line between Genoa and Massa may be considered as parallel to it, and roughly the coast-line between Pescara and Brindisi on the east side of Italy.

The coast-line from Ancona to Pescara may be considered as correlated with it by the angle 40°, as also the coast-line between the Gulf of Policastro and Gulf of Santa Euphemia.

II.—*Marseilles, Toulon, and Laybach Line.*—The coast-line direction and earthquake locus just considered meets at Parma the very remarkable line extending from Marseilles and Toulon to Laybach, over a distance of about 500 miles, well marked by repeated shocks, sometimes local only, at others having extended along the whole line. This line might in reality be considered as extending to Barcelona, in Spain, and as regards correlation may be taken as making an angle of 80° with the east coast of England direction (No. 56).

It might also be considered as parallel to the direction of the Murcia earthquake zone, which, parting from near Almeria, is drawn on the map at an angle of 70° with No. 6 (west coast of Africa).

To the west this Marseilles-Laybach line cuts the Spanish coast at Cadiz; to the east it passes through Hungary, running about thirty miles north of the Balaton Lake, and parallel to its axis. It passes at Pesth, runs parallel to and to the north of the earthquake line which extends from Kardzag to Szathmar Nemeths. It there meets the earthquake line which extends from Lemberg in Gallicia to Hermannstadt in Transylvania, making with it an angle of about 70°.

III.—*East Coast of Sardinia Line.*—At Parma the two last described directions are intersected by another, equally well marked—that is, the line represented by the east coast of Sardinia, drawn on the map at 80° with the north coast of Africa (No. 14), but which might also be considered as a parallel to the east coast of Sweden direction (No. 51).

This east coast of Sardinia direction passes through Elba, runs parallel to the Leghorn coast-line, passes at Parma, between which city and Leghorn simultaneous shocks of earthquakes have frequently occurred, follows the west side of the valley of the Adige, and touches in its extension the western side of the Saxony earthquake district.

IV.—*East Coast of Sweden Direction.* — This direction, nearly parallel to the last described, is much more distinctly marked in its characteristics as a line of earthquake action.

Its correlation with the great circle coast-line directions is 40° with No. 50 (Promontory of New Ulster).

That portion of it extending from Nordköping to Karlscrona is well marked by its rectilineal direction. Farther south it passes at Prague, Undine, Rimini, and mouth of the Tiber; traversing the Tyrrhenian Sea, it cuts the African coast at Cape Bon and at Sfax. As regards this portion of the line, it may be remarked that up to the present (23rd July, 1881) there had not been recorded (in the lists consulted) any earthquake as having taken place along this coast of Tunis, although theoretically the extensions of the coast-line directions already described would point out this country as one of earthquake action. Now, owing to the presence of scientific observers in this country, within the last month or so we receive intelligence of an earthquake or earthquakes having taken place in and about the Gulf of Gades; and, furthermore, notice of the fact that the constitution of the country is volcanic. I cite this fact to show how those lines may be interpreted as regards districts but little explored.

The section of this line between Rome and Rimini is one of the best-marked earthquake lines in Italy, while the section between Pola and Brück is also well defined as a direction by a series of points along which shocks have been continually occurring. Between Palermo and Naples a parallel to this coast-line direction seems to be marked out by earthquake movements, cited as having extended from one point to the other (April 16, 1817).

V.—*Bari Coast-line Direction.*

VI.—*Policastro-Nicastro Coast-line Direction.*—The southern or Calabrian part of Italy presents two coast-line directions, well marked by earthquake action, the one represented by the line extending from the Gulf of Manfredonia south-eastwards, the other by the Val de Diano and the coast-line on to Nicastro. This one is very strongly marked, and distinctly parallel to the great circle direction, south-east coast of Africa or Sofala coast (No. 24).

VII.—*East Coast of England Direction.*—A very remarkable coast-line direction is that representing the east coast of England. It is correlated with the great circle direction No. 12 (River St. Lawrence, or southern boundary of tertiary formation, United States), by the angle of 40°.

As shown on the map it runs parallel to the east coast of Iceland, traverses the Ferroe islands, parallel to the axis of the main island, runs along the east coast of Hoy island in the Orkneys, touches Scotland at Kinnaird's Head, runs parallel to the east coast of England from the Firth of Forth to the Wash; passes at Bruges, traverses the well-marked earthquake district which extends from the plateau of Langres by Geneva and Savoy to Nice; traverses Sardinia, cutting its coast-line at Cagliari; cuts the Tunisian coast, passes at Tunis, and enters Africa proper at Jerba island in the Gulf of Gades.

That portion which extends from the plateau of Langres to Nice only partially represents an earthquake line, although Geneva, Savoy, and Nice may be considered as constituting one; but the parallel to this coast-line represented as passing through the island of Elba presents a well-defined character. Thus parting from the Shetland islands, it traverses the Zuider Zee at Harderwick, and marks well in its extension the western boundary of the Rhine valley earthquake district. The central axis of this, which may be taken as extending from Gross Gerau to Stuttgard, is parallel to it. The continuation of that axis, from Stuttgard southwards to the vicinity of Parma, may also be taken as representing a line of earthquake action, though not so distinctly marked as the more northerly portion.

VIII.—*West Coast of Africa Coast-line Direction* (*No.* 6).—This coast-line direction enters Spain at the Cabo de Gata, passes near Madrid, cuts the Santander coast at Santillana, crosses the Bay of Biscay, and meets the Irish coast at Cork—one of the localities in Ireland, the best marked as regards frequency of occurrence of earthquakes. Its continuation northwards runs along the west coast of Iceland, and practically parallel to it. As an earthquake line it is not very remarkable over this extent, but there seems to be developed parallel to it a line of earthquake localities, extending from Tarbes by Bordeaux and Nantes on to the coast of Dorsetshire, through the Channel islands.

This line is very distinctly marked, and may be considered as the axis of a zone or band which would include the eastern portion of Spain, the western half of France, Great Britain and Ireland, the Faroe Islands, and Iceland.

IX.—*The Almeria or Murcia Earthquake District* may be considered as correlated with this line by the angle of 70°. It has a well-marked direction, and its extension eastwards represents the coast-lines of Iviza and Majorca, crosses the northern part of Corsica, touches Elba, and traverses Italy from Piombino by Sienna Arezzo and Urbino—points well marked by repeated earthquake movements.

X.—*South-east Coast of the Adriatic* (*Allesio to Aolona*).—This line, of no great extent, yet well marked as regards earthquake movements, is interesting from the fact that its parallel, lying between Bosnia-Serai and Ragusa, has been cited as a line along which simultaneous earthquake action has taken place (June 27, 1869). Now, this line may be considered as making with the coast-line, north-east of the Persian Gulf (No. 32) an angle of 80°, and produced defines correctly the line of the Danube between Waitzen and Essek, along which shocks have been cited as having occurred, parallel to which there is a very distinctly marked line of earthquake action represented by a series of points between Kesskemet and Petervasara in Hungary.

As regards the coast-lines, properly so called, certain of them are well marked by the frequency of earthquakes and succession of the points at which they have been noted. This is the case as regards the west coast of Portugal, the north coast of Africa, the Syrian coast, the Adriatic coasts, the western coast of Asia Minor, the north-east coast of the Black Sea, the southern coast of same between Samsun and Trebizonde. The northern or Cantabrian coast of Spain, so markedly rectilinear and so well defined by the great circle, No. 66 (south-west coast of Australia), is not cited as having presented remarkable earthquake movements; yet the few localities cited in this respect are upon this great circle. Taking into consideration only those more remarkable coast-line directions, their parallels, and certain lines correlated therewith, it may be advanced that they furnish sufficient evidence to justify the proposition, that between certain of these coast-line directions and localities in Europe markedly characterized by the frequency and intensity of their earthquakes, there exists a very distinct relation of direction, and that this relation would be much more distinct were our earthquake records more complete, and if they had extended over a greater period of time than that corresponding to our chronology, a period so comparatively short so far as geognostical factors are concerned.

Many minor proofs of parallelism and correlation might be pointed out, and may be easily gathered from the examination of a map.

Thus, examining the Rhine valley earthquake district, it may be observed that not only is it well defined on the west by the east coast of England direction, but that, moreover, the locality of relatively greatest intensity, which may be taken as corresponding to Gross Gerau, occurs at the intersection of the great circle direction, Axis of Sumatra (No. 28), with the parallel to the coast of England passing through Elba.

Furthermore, the great circle direction No. 56, Promontory of New Ulster, passes somewhat to the south thereof at Strasburg and Carlsruhe, and defines sufficiently the northern boundary of the Saxony central earthquake district. This district may, indeed, be defined as bounded on the north-west and south-east by this great circle, and a parallel thereto, and on the north-east and south-west by the great circle, east Cape of Madagascar (No. 2), and a parallel thereto. This great circle (No. 2), and those representing the east and west coasts of the Red Sea, are very characteristic in their intersections, and all pass through Iceland, and would suggest a possible connexion between the volcanic and earthquake activity of that island and localities situated on these great circle directions. Such connexion or simultaneity of action at points of a coast-line direction wide apart is demonstrated by the repeated occurrence of shocks at Græchen in Switzerland and Constantinople, on the same day and nearly same hour, both points being situated on a parallel to the north-east coast of the Persian Gulf (No. 32). It is evidently of extreme importance to follow out these relations, since, if established for points at great distances on great circle directions, every new relation thus established between phenomena apparently isolated and unconnected points towards a law, and would be of a nature to guide physicists as to the localities whereat seismographs may be most advantageously established for observation.

These considerations lead up to the examination of the second point which I proposed to consider, that is, the relations to be established between these coast-line directions considered as great circles and localities situated outside Europe, and noted for the frequency or intensity of their earthquakes. In order to do so in a summary manner I have detailed the points through which these great circles pass, printing in thick type the known earthquake localities, and in italics those known only on account of volcanic action.

No. 2.—EAST CAPE MADAGASCAR.

Antigonil Bay.
Astone and Cosmoledo Islands.
Abyssinia, . . . Near Gondar.
Nile, ... At Syene, First Cataract, Mineah.
Mediterranean Coast, . Arabs Gulf.
Candia, ... Near Cape Sidero.
Sporades.
Eubœa Island, . . (Twelve miles east of).
Killodromi Island.

Salonica.	
Servia.	
Hungary,	Betwen **Essek** and Zombor, **Mohacs, Funfkirchen, Balaton Lake.**
Austria,	**Vienna.**
Bohemia,	**Prague, Eger, Erzgebirge Mountains.**
Saxony,	**Chemnitz, Leipzig, Dresden.**
North Germany,	**Elbe Mouths.**
Shetland Islands,	(Seventeen miles south of).
Faroe Islands.	
Iceland,	**Vatna, Jokull, and north-west point of.**
Greenland.	
Canada,	Hudson's Bay, Cape Churchill, Winnipeg and Deer Lakes.
Oregon and California,	Cape Conception.
Marquesas Island.	
Poumota or Low Archipelago.	
Sabrina Land.	
Kerquelan Land,	(Thirty-three miles south of).

No. 3.—WEST COAST OF RED SEA.

Africa,	Makdishu, Somali Coast, **Nile Mouths,** Damietta.
Rhodes and west coast of Asia Minor,	**Samos, Mytelene.**
Turkey,	Kara Su. R., **Sofia.**
Servia.	
Hungary,	**Szegedin, Buda-Pesth, Kremnitz.**
Bohemia,	**Kœniggratz.**
Silesia,	Gorlitz.
Prussia,	**Berlin, Potsdam.**
Denmark,	**Ribe.**
Shetland Is.,	**Lerwick.**
Faroe Is.	
Iceland,	**Vatna Jokul,** and north-west point of.
Greenland.	
Canada,	Hudson's Bay, near Port Nelson; Winnipeg Lake.
Utah,	**Salt Lake,** south-east point of.
Californian Coast,	Catalan Is.
Marquesas Is.	
Paumota Group.	
Adelie Land.	
Sabrina Land.	
Bourbon Is.,	(Twenty-three miles east of).

No. 4.—EAST COAST OF RED SEA.

Seychelle Is.	
Gulf of Aden,	Berbera.
Arabia,	Mocha.
Red Sea,	*Farsan Is.*, Head of Acuba Gulf.
Cyprus,	Fifty miles west of C. Arnauti.
Asia Minor,	South Coast, C. Kiledonia, **Sources of Menander,** Twenty miles west of **Ushak.**
Sea of Marmora.	
Wallachia.	

Hungary,	**Debrezin, Karchan.**
Silesia,	**Breslau.**
North Germany,	Landsberg.
Denmark.	
Shetland Is.,	**North Unst.**
Iceland,	Kressonaes, Glamn Jokul.
Greenland.	
Canada,	Hudson's Bay, North-west point Labrador, Winnipeg Lake.
California,	Course of River Colorado, Head of Gulf of California.
Marquesas Is. and Society Is.	
Sabrina Land.	
Adelaide Land.	

No. 5.—COAST OF SYRIA.

Syrian Coast,	**Gaza, Beyrout, Tripoli, Antioch, Iskanderoon.**
Asia Minor,	Near Sivas, **Unieh, Black Sea Coast.**
Circassia,	Michelowski.
Caucasus,	Mount Papnii, near Ekaterinodar.
Russia,	Near Nyzni Novogorod, runs parallel to the course of the Volga between Tenatitin and Kaimishin.
New Siberia,	Head of Taimurski Bay.
North-east Siberia,	Chaunskara Bay, C. Alyastorski.
Alentian Is.,	Atcha Is.
Sandwich Is.,	**Tani Is.**
Society Is.,	Tahiti Is.
Africa,	*South-west Coast*, St. Helen's Bay, cuts the Equator at 26° E. Long. near bend westward of Congo, *Nile* (2nd and 3rd cataracts), Egypt, Keneh, Peninsula of Sinai.

No. 7.—WEST COAST OF MOROCCO.

Spain,	**Guadiana Mouths,** Albuera, Caceres, Palencia, Salamanca, Mts. of Europe, Santander Coast, Deva R. Valley.
France,	**Loire R. Mouth, St. Malo, Cherbourg Promontory.**
England,	**Brighton,** North coast of Norfolk.
Norway,	Flekkifiord, West of the Naze, Sytle Fiord, *Valley of the Tanie R.*
Nova Zembla,	
Siberia,	Jigansk, on the Lena; South-east course of the R. Lena.
Sea of Okhotsch,	Shanter Is.
Amour R.,	Mouths of.
Sagalin Is.,	**Jesso Is.,** north-east point of.
Solomon and Santa Cruz Is.,	Passes between them.
New Caledonia,	South-east point of, Loyalty Is.
New Ulster,	C. and Mt. Egmont, Cooke's Sound.
South Shetland.	
South Georgia Is.	
Africa,	West coast, Bissagos Is.; Morocco, West coast from C. Blanco to C. Juby.

No. 12.—SOUTHERN BOUNDARY TERTIARY FORMATION, UNITED STATES.

Gulf of Mexico,	Victoria Fort.
Canada,	Lake Erie, Buffalo, **Lake Ontario,** Trenton, **R. St. Lawrence** (parallel to course of), **Ottawa,** Anticosti Is. (north-west point of), **New Brunswick, Coast of the R. St. Lawrence.**
Labrador,	South Coast, York Point, Straits of Belle-Isle.
Ireland,	Shannon Mouth, Foynes.
Wales,	**South Coast, St. Bride's Bay, Oystermouth, Weston-super-Mare.**
England,	**Mendip Hills, Southampton.**
France,	**North of Dieppe.**
Switzerland,	**Basle.**
Tyrol,	**Trent.**
Italy,	**Venice.**
Dalmatian Coast,	**Herzegovina and Montenegro.**
Turkey,	**Monastir,** North of Mt. Olympus.
Ægean Sea,	Skyros, Cos, **Rhodes.**
Syrian Coast,	El Arish.
Arabia,	Mt. Siebam, C. Guardafiu.
South Pacific,	Pamuan Is.
Mexico,	West Coast, near Guadalajala; C. Corrientes; Zacatecas Territory.

No. 14.—NORTH COAST OF AFRICA.

Ceuta,	**Alboran Is., Coast of Algiers.**
Sicily,	**Mt. Etna.**
Morea,	**Argos.**
Asia Minor,	**South Coast of,** Malesso, Saletkeh.
Cyprus,	North of.
Syria,	**Antioch, Aleppo.**
Persia,	**Ispahan.**
Beloochistan,	Khozdar, Sheivan.
India,	**Viziampatam.**
Andeman Is.,	North Sentinel.
Malaya.	
Borneo,	South-west point of.
Sambawa Is.,	East point of.
North Australia,	Cambridge Gulf; runs parallel to south coast of Carpentaria Bay.
New South Wales,	C. Byron.
New Ulster,	Bay of Islands.
Peru,	North-west point of, Loja, Lobos Is.
Ecuador,	Santa Rosa.
New Granada,	Moreno, Orinoco R. Mouths.
Madeira Is.,	St. Laurence.

No. 15.—WEST COAST OF PORTUGAL.

Mogador.	
Portugal,	C. St. Vincent, **Lisbon, Oporto.**
Spain,	**Vigo, Santiago, Corunna.**
Ireland,	Waterford, Coast of Antrim.

Scotland,	**Mull and Skye Is.**
Faroe Is.,	Eastern group of.
Spitzbergen,	Hackluyts Headland.
East Siberia,	Nigui-Kolinsk.
Nigui Kamtschatka Coast.	
Musquito Group.	
New Hebrides,	Southern Group of, **Tanna Is.**
New Munster,	C. Foulwood to Ashburton.
Liberia (Africa),	Monrovia Town.
Sahara (Africa),	Parallel to line from C. Blanco to C. Verd.

No. 16.—EAST COAST OF ENGLAND.

Yarmouth,	Pentland Head.
Faroe Is.,	Sunderoe.
Greenland,	Scoresby's Sound, C. York.
Barrow's Straits,	Victoria Land.
Canada,	Great Bear Lake, North-west point of.
Alaska,	Sitka Is., Falls of R. Francis.
Sandwich Is.,	1° 20′ to the east of.
Enderby's Land.	
Africa,	Kaffraria Coast, R. Untainvoona, **North-east coast of Tunis.**
Sardinia,	**Cagliari,** Asinara Is.
France,	**Antibes, Chambery, Dijon, Laon, Chalons.**

No. 23.—CAUCASUS MOUNTAINS.

Balkan Mountains and Gulf,	Naphtha Springs.
Baku.	
Sea of Azof.	
Russia,	Parallel to the course of the Dnieper.
Carpathians,	North side of, Eighteen miles south of Lublin.
Germany,	**Berlin** and **Potsdam.**
Holland,	**Zuyder Zee,** Texel.
England,	North coast of Norfolk, **Nottingham, Derby.**
Wales,	**Carnarvon Promontory.**
Ireland,	**Wicklow,** Shannon (lower course of).
West India Is.,	Windward Pass.
Central America,	Costa Rica and Panama frontier, between *Mount Chirigin* and *Pico Blanco.*
Gallipagos Is.,	**Easter Is.**
Aukland Is.,	South of.
West Australia,	South-west part of Seal Is., West Coast, Arrowsmith R. Mouth.
India,	East Coast, Sadras.
Cutch Is.,	**Surat,** Gulf of Cambay, **Hyderabad.**
Afghanistan,	Kelat.
Persia,	Nisapoor.

No. 24.—SOUTH-EAST COAST OF AFRICA (FROM SOFALA BAY SOUTHWARDS).

Sofala, ...	C. Corrientes.
Marian and Crozettes Is., .	1° west of.
South Victoria, . . .	Cook's or Harvey's Is. Group.
North America, . . .	Queen Charlotte Is., Provost Is., Wellington Bay, North Devon Is. (C. Horsborough).
Greenland, . . .	Melville Bay, Davy's Sound, Verner Mountains.
Europe, ...	Mouths of Weser R., **Minden, Hanover, Gottingen, Bamberg, Noric Alps, Carnic Alps.**
Italy, ...	**Undine, Gulf of Trieste, Adriatic**, Pola Coast, parallel to coast between **C. Policestro** and **C. Santa Euphemia, Basilicata, Cosenza.**
Africa, ...	East coast of G. of Sidra, East coast of Tanganaika Lake.

No. 28.—AXIS OF SUMATRA.

Nicobar Is.	
East Coast of India, .	**Bomlipatam.**
India, ...	Mooltan, **Lehree Fort, Cabul**, near Candahar.
Caspian Sea, . . .	Karaboghaz Bay, **Derbent.**
Caucasus, . . .	**Ekaterinodar.**
Sea of Azof, . . .	Czernowicz.
Carpathian Mountains, .	Hungary, **Kesmak.**
Moravia, ...	**Bohemia**, Ireslau.
Germany, ...	**Odenwald, Wurtzburg, Worms.**
Rhine, ...	**Luxembourg.**
France, ...	**Brittany, Rouen, Caen**, C. Ushant.
Jersey.	
Azores, ...	About 2° north of.
West India Is., . .	Spanishtown.
South America, . . .	**Paraguana Peninsula, L. Mascaybo, New Granada, Medelin**, Bay of Choco.
Ecuador and Granada, .	North-west coast, from Beneventura Bay to C. Lorenz.
New Zealand, . . .	South point of, South-west Cape, Long Is.
Tasmania, ...	North point of.
Australia, ...	Coast-line from Geelong to Australian Bight.
Java Is., ...	South-west point.

No. 32.—NORTH-EAST COAST OF PERSIAN GULF.

Euphrates R. Valley, .	**Bagdad**, thirty miles south-west of.
Aleppo, ...	**Head of Iskanderoon Gulf.**
Asia Minor, . . .	**Taurus Chain, Konieh, Karahissar, Broussa.**
Sea of Marmora, . .	**Gallipoli.**
Turkey, ...	About forty miles south of **Sophia, Bosnia Serai.**
Dalmatian Coast, . .	**Zara.**
Italy, ...	**Po River Valley, Mantua, Milan, Chambery.**
France, ...	Rhone, at **Lyons.**
Cuba Is., ...	**Buena Esperanza Bay.**
Nicuaragua, . . .	Near the Lake, Leon.
New Zealand, . . .	North point of Long Is.
Tasmania, ...	South point.
Australia, ...	South-west Promontory.
Lacadive Is.	
Arabia, ...	Muscat Coast.

No. 50.—PROMONTORY OF NEW ULSTER.

C. Maria, Van Diemen.
South America, . . . **Patagonia**, Port Santa Cruz, C. Frio, and Coast-line to Espiritu Santo.
North-west Africa, . . From C. Blanco to Mazagran.
Spain, ... Guadalquiver R., **Seville, Toledo.**
Pyrenees, ... **Pic du Midi, Bagniere de Bigorre.**
France, . . . **Cantal, Chalons sur Rhone.**
Germany, ... **Strasburg, Mannheim, Heidelberg, Wurtzburg, Darmstadt, Weimar, Leipzig**, Danzig.
Russia, ... Ural Mountains, Pas Mer Mountains.
Siberia, ... Course of Obi at Surgutoi, **Backal Lake, Oudonsk.**
China, ... **Corea, Kinsin Is.**, *Solomon Is.*

No. 51.—EAST COAST OF SWEDEN.

Carlscrona, Stockholm, **Gefle, Hermosand, Umea.**
North Cape.
Siberia, ... Tchaon G., Amtschitka Is., **Alustran Is.**
Samoa Is., ... Oyolava Is.
Atlantic Ocean, . . . St. Thomas Is.
Africa, ... Niger Mouths (parallel to Gaboon Coast), **Tunis**, C. Bon and East Coast.
Italy, ... **Rome to Pesaro.**
Adriatic, ... **Trieste Coast and Gulf, Undine.**
Austria, ... **Carnie Alps, Styria.**
Bohemia, ... **Prague.**
Prussia.

No. 53.—EAST COAST OF NEW ZEALAND.

Sabrina Land.
Marian and Crozetto Is.
South Africa, . . . C. Vidal.
Algiers, ... **Tlmencen, Hilat.**
Spain, ... **Vera, Lorca**, Madrid, **Escurial**, C. Ortugal.
Greenland, ... South-east Coast, Baffin's Is., Chesterfield Inlet.
Vancouver's Is., . . . North point.

No. 52.—WEST COAST OF SWEDEN.

Greenland, . . . Ardencaple Inlet.
North America, . . . Smyth's Straits, Alexander Cape, Great Bear Lake, Graham Is.
South Victoria, . . . *Mount Erebus.*
Africa, ... Sofala Coast, Lybian Coast.
Morea, ... Axis of.

No. 66.—SOUTH-WEST COAST OF AUSTRALIA.

Tasmania,	South point.
New Munster,	From Milford Sound to Ashburton.
Gambar Is.,	Paumoa Group.
Central America,	**Guatemala**, Quisaltenango to C. Catoche.
Cuba,	North-west Coast.
North America,	Florida Point.
Spain,	**Pyrenees**, and Santander Coast.
Sardinia,	Straits of Bonifacio.
Southern Italy, Candia Is.	**Catanzaro.**
Red Sea,	Head of Gulf of Acaba.
Arabia,	South Coast, Dofar.

These details show that the great circles marked on the map of Europe, in connexion with earthquake disturbances, traverse outside Europe, countries and districts more or less markedly subject to earthquakes, or volcanic in their nature, and therefore it would be possible to refer to such great circles the several earthquakes occurring on their directions. This would be a first method of grouping, and would allow of comparisons as regards contemporaneity, or, what is of equal interest, regularity of interval between the shocks occurring at points distantly removed.

The referring of earthquakes to great circle directions would, furthermore, facilitate the definition of those large extents of globe surface affected by great earthquakes, such as that of Lisbon in 1755, which can be very conveniently defined in this manner. Such earthquakes, and indeed many others, have usually been represented as extending over an ellipsoidal or circular space. This mode of definition can only be approximative, and when the limits are at all accurately determined, the surface affected usually presents a polygonal form. Thus the great earthquakes of 1811–13 are marked on Berghaus' map as extending over a triangular space, having for summits the Azores, the valley of the Ohio, and New Granada, that is to say, a polygonal form capable of being defined by segments of great circles.

The northern side of this triangle corresponds fairly with the great circle (No. 55) axis of Bay of Fundy, which runs from Madeira to Omaha (Nebraska State), about the extent of that side of the triangle. It might, therefore, be correct, and would be convenient, to refer and define earthquakes relatively to the great circles along which or near the intersections of which they occur. This I have done in the present memoir for the Central Saxony earthquake district, so remarkably connected with the great circle directions No. 50 and No. 2, and parallels.

I have also taken the records for 1870–78, and referred the successive earthquakes to great circle directions with very interesting results; and in certain cases, where the limiting points are given, the concordance of the boundaries of the locality affected, with the coast-line directions passing thereat, is very remarkable.

Of the lines correlated with the great circles, and marked on the map, the following are the most remarkable :—

Great Circles.	Lines.	Angle of Correlation.
With No. 5.—Coast of Syria.	Axis of Cyprus, ...	40°.
,, ,, ,,	Black Sea Coast, Environs of Kerasun and Trebizonde, ...	70°.
,, ,, ,,	North-east Coast of Black Sea, Circassian Coast, ...	70°.
,, ,, ,,	West Coast of Caspian Sea, between mouths of Volga and Gulf of Kama, ...	Parallel to.
,, ,, ,,	Volga Course, between Tzaritzin and Caspian Sea, ...	70°.
,, ,, ,,	Volga Course, between Tzaritzin and Kamishin, ...	Parallel to.
,, ,, ,,	Ural Range, from Shadmatra to Ekatermburg, ...	40°.
,, ,, ,,	Ural Range, north of Shadmatra, .	Parallel to.
,, ,, ,,	North Coast of Lapland and Timan Range, ...	70°.
,, ,, ,,	East Coast of Black Sea, between Anaklia and Fort Santa Nickolai,	40°.
With No. 16.—East Coast of England.	Catania, Coast of Sicily, and West Coast of Gulf of Taranto, . .	40°.
With No. 6.—West Coast of Africa.	Murcia Earthquake Zone, . .	70°.
,, ,, ,,	Ebro R. Valley Line (an Earthquake Line), ...	40°.
With No. 32.—North-east Coast of Persian Gulf.	Line joining Bosphorus and South-east Coast of Crimea (an Earthquake Line), ...	70°.
,, ,, ,,	South-east Coast of Adriatic, from Aolona to Alessio, . . .	80°.

Great Circles.	Lines.	Angle of Correlation.
With No. 51.—East Coast of Sweden.	Coast of Tripoli, from Jerba Is. to C. Mesurata.	80°.
,, ,, ,,	South Coast of Gulf of Sidra, from Zafran to Kudia, . . .	80°.
,, ,, ,,	North-west Coast of Gulf of Cabes, .	40°.
,, ,, ,,	Line joining Kalibia (Cape Bon), Malta and Barca Coast, . .	80°.
,, ,, ,,	South Coast of Sicily, . . .	70°.
,, ,, ,,	South Coast of Gulf of Finland (Narva Bay), ...	70°.
,, ,, ,,	Southern Shore of Lake Farouri (Tunis), ...	70°.
With No. 52.—West Coast of Sweden.	South Coast of Crete, . . .	70°.
,, ,, ,,	Coast of Egypt, from Milhr Bay to Galla Bay, ...	70°.
,, ,, ,,	Axis of Euboea Is., ...	40°.
,, ,, ,,	Axis of Lake Wetter, . . .	40°.
,, ,, ,,	East Coast of Œland Is., . .	40°.
,, ,, ,,	East Coast of L. Wener and Axis of Porsanger Fiord, . . .	40°.
,, ,, ,,	General direction of Kiolin Mountains, ...	40°.

LXXIII.—A Geometrical Representation of a System of Two Binary Cubics and their Associated Forms. By W. R. Westropp Roberts, M.A.

[Read, November 14, 1881.]

I.

The object of this Paper is to invest with a certain geometrical meaning the algebraic forms arising in a system of two binary cubics, that is, to construct geometrically points which shall represent the linear, quadratic, cubic, and quartic covariants of the system, and to express the vanishing of invariants by geometrical relations connecting such points. We may consider any binary quantic as derived from a system of three surfaces by assuming

$$X=\phi_1(x_1x_2),\quad Y=\phi_2(x_1x_2),\quad Z=\phi_3(x_1,x_2),\quad W=\phi_4(x_1,x_2),$$

equations which in themselves imply, by elimination of x_1 and x_2, two fixed relations between X, Y, Z, W, denoting a fixed curve in space, while the given binary quantic, equated to zero, enables us to obtain a third such relation. The transformation here employed is one in which ϕ_1, ϕ_2, ϕ_3, ϕ_4 are cubic functions of x_1 and x_2. By linear transformation this substitution is reducible to

$$X=x_1^3,\quad Y=x_1^2x_2,\quad Z=x_1x_2^2,\quad W=x_2^3,$$

the fixed curve in this case being evidently a twisted cubic. The equation of an osculating plane of the curve, the parameter of the corresponding point of which is $x_1:x_2$, being (Salmon's *Geometry of Three Dimensions*, Art. 368)

$$Xx_2^3-3Yx_2x_1^2+3Zx_1^2x_2-x_1^3W=0,$$

the parameters answering to osculating planes through any point O, the co-ordinates of which are X', Y', Z', W', are given by the equation

$$x_2^3X'-3Y'.x_2^2x_1+3Z'.x_1^2x_2-x_1^3W'=0,$$

the points of contact lying in the plane

$$XW'-3YZ'+3Y'Z-WX'=0.$$

But this plane passes through O, the given point. To any plane, then, corresponds a point O, the point of intersection of the osculating planes at the points where it meets the curve—a point which plays an

important part in the following investigation. It can readily be shown that if a point O' lie in the plane corresponding to a point O, then O lies in the plane corresponding to O', and the line joining O and O' possesses a certain invariant relation to the curve. Also the locus of the corresponding points of planes passing through a given line is a right line, which may be called the corresponding line to the given one, their relation being reciprocal.

Let us now consider the binary cubic—

$$f \equiv a_0 x_1^3 + 3a_1 x_1^2 x^2 + 3a_2 x_1 x_2^2 + a_3 x_2^3 = a_x^3 = b_x^3 = c_x^3, \text{ \&c.,}$$

adopting Clebsch's notation.

By our transformation the binary cubic is transformed into a plane f, the equation of which is—

$$a_0 X + 3a_1 Y + 3a_2 Z + a_3 W = 0.$$

Now it can be easily shown that the corresponding point of this plane is given by the equations

$$X = a_3, \quad Y = -a_2, \quad Z = a_1, \quad W = -a_0.$$

We shall call it the point O.

II.

It is known that through any point O in space can be drawn one chord, meeting the curve in two points. Let us now determine these points, being given the point O.

The co-ordinates of the line joining the points on the curve, the parameters of which are $x_1 : x_2$, $y_1 : y_2$, respectively, are easily found to be—

$$a = \Delta_0 \Delta_2, \qquad f = 4\Delta_1^2 - \Delta_0 \Delta_2,$$
$$b = 2\Delta_1 \Delta_2, \qquad g = -2\Delta_1 \Delta_0,$$
$$c = \Delta_2^2, \qquad h = \Delta_0^2,$$

where

$$\Delta_0 = x_2 y_2, \; 2\Delta_1 = x_1 y_2 + y_1 x_2, \; \Delta_2 = x_1 y_1.$$

Now take two equations of the chord, viz. :—

$$aX + bY + cZ = 0,$$
$$hY - fZ + aW = 0,$$

and these furnish us with—

$$\Delta_0 X + 2\Delta_1 Y + \Delta_2 Z = 0,$$
$$\Delta_0 Y + 2\Delta_1 Z + \Delta_2 W = 0.$$

If we now suppose $X = a_3$, $Y = -a_2$, $Z = a_1$, $W = -a_0$, the equation determining the parameters of the two points in which the chord through O, the corresponding point of f, meets the curve is—

$$(a_0a_2 - a_1^2)x_1^2 + (a_0a_3 - a_1a_2)x_1x_2 + (a_1a_3 - a_2^2)x_2^2 = 0.$$

But this is the equation of the Hessian of f, or—

$$\Delta_x^2 = \Delta_0x^2 + 2\Delta_1x_1x_2 + \Delta_2x_2^2.$$

Thus, then, to the Hessian of f correspond the two points in which the chord through O meets the curve.

III.

I shall now show that the plane f passes through the line of intersection of the osculating planes at the two Hessian points. To prove this, let us find the equation of the plane through O and this line.

Let

$$X', Y', Z', W'; \quad X'', Y'', Z'', W'',$$

be the co-ordinates of the two Hessian points, respectively, then the equation of such a plane must be—

$$\lambda(XW' - 3YZ' + 3ZY' - WX') - \mu(XW'' - 3YZ'' + 3ZY'' - WX'') = 0,$$

where

$$\lambda = a_0X'' + 3a_1Y'' + 3a_2Z'' + a_3W'',$$
$$\mu = a_0X' + 3a_1Y' + 3a_2Z' + a_3W'.$$

Remembering that

$$x_1y_1 = a_1a_3 - a_2^2,$$
$$x_1y_2 + y_1x_2 = a_0a_3 - a_1a_2,$$
$$x_2y_2 = a_0a_2 - a_1^2,$$

we find, dividing by a factor $y_1x_2 - x_1y_2$, that the equation of the sought plane is—

$$R\{a_0X + 3a_1Y + 3a_2Z + a_3W\} = 0.$$

Hence the plane f passes through the line of intersection of the osculating planes at the Hessian points. If, then, the chord through O meet the cubic in real points, the plane f must meet it in two imaginary points, since the binary cubic is then the difference of two cubes.

IV.

Let us now determine the co-efficients of the plane

$$\lambda(XW' - 3YZ' + 3ZY' - WX') + \mu(XW'' - 3YZ'' + 3ZY'' - WX'') = 0,$$

and we find, after a few obvious reductions, that it becomes—

$$R\{(a_0^2a_3 - 3a_0a_1a_2 + 2a_1^3)X + 3(a_0a_1a_3 + a_1^2a_2 - 2a_0a_2^2)Y + 3(2a_1^2a_3 - a_0a_2a_3 - a_1a_2^2)Z + (3a_1a_2a_3 - a_0a_2^2 - 2a_3^3)W\} = 0,$$

but this is the cubic covariant plane Q.

We see, then, that the planes f and Q are harmonically conjugate with regard to the osculating planes at the Hessian points, and that since the Hessian of the cubic Q_x^3 is the same as that of a_x^3, the corresponding point of the plane Q lies on the chord through O, and is the harmonic conjugate of O with regard to the Hessian points. Hence, to the cubic covariant corresponds the plane through the intersections of the osculating planes at the Hessian points and the harmonic conjugate on the chord through O of the same point with regard to the Hessian points. Again, if the point O lie at one side of the developable generated by tangent lines to the cubic curve from which a real chord can be drawn, two of the roots of the binary cubic are imaginary; if the point O lies on the developable, two roots are equal; and if at the other side, from which a real chord cannot be drawn, all the roots are real.

V.*

We can now discuss the system of two binary cubics and their associated forms, and shall adopt the notation of Clebsch in our investigation. Let then f and ϕ denote the two cubics, Δ and ∇ their Hessians, Q and K their cubic covariants, and R and P their discriminants.† We have then

$$f \equiv a_0x_1^3 + 3a_1x_1^2x_2 + 3a_2x_1x_2^2 + a_3x_2^3 = a_x^3 = b_x^3 = c_x^3 = \&c.;$$
$$\phi \equiv \alpha_0x_1^3 + 3\alpha_1x_1^2x_2 + 3\alpha_2x_7x_2^2 + \alpha_3x_2^2 = \alpha_x^3 = \beta_x^3 = \gamma_x^3 = \&c.$$

There is one quartic form, $(a\alpha)\,a_x^2\alpha_x^2$, which we shall first discuss. The co-ordinates of the line of intersection of the planes f and ϕ are,

$$a = a_0\alpha_3 - a_3\alpha_0, \qquad f = 9\,(a_1\alpha_2 - a_2\alpha_1),$$
$$b = 3\,(a_1\alpha_3 - a_3\alpha_1), \qquad g = 3\,(a_2\alpha_0 - a_0\alpha_2),$$
$$c = 3\,(a_2\alpha_3 - a_3\alpha_2), \qquad h = 3\,(a_0\alpha_1 - a_1\alpha_0),$$

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* See Note at end of this Paper.

† The reader is referred to Clebsch's *Theorie der Binären Algebraischen Formen*, § 61. Vollständiges System zweier cubischen Formen.

while the co-ordinates of a tangent line are

$$\begin{aligned} a &= x_1^2 x_2^2, & f &= 3x_1^2 x_2^2, \\ b &= -2x_1^3 x_2, & g &= 2x_1 x_2^3, \\ c &= x_1^4, & h &= x_2^4. \end{aligned}$$

Forming then the well-known condition that these lines should meet, we find

$$x_1^4(a_0a_1 - a_0a_1) + 2x_1^3x_2(a_0a_2 - a_2a_0) + x_1^2x_2^2\{a_0a_3 - a_3a_0 + 3(aa_1a_2 - a_1a_2)\} + 2x(a_1a_3 - a_1a_3)x_1x_2^3 + (a_2a_3 - a_3a_2)x_2^4 = 0,$$

or,

$$(aa)\,a_x^2 a_x^2 = 0.$$

Hence, to the Jacobian of f and ϕ correspond the four points on the curve, the tangents at which meet the line f, ϕ.

It is to be observed that these four lines also meet the line corresponding to the line f, ϕ. The Jacobian is thus geometrically shown to be a combinantive covariant, since it depends only on the position of the line f, ϕ.

VI.

In addition to the forms f and ϕ, and their cubic covariants, there are two cubic forms,

$$(a\nabla)\,a_x^2\nabla_x,\ (a\Delta)\,a_x^2\Delta_x,$$

which we now discuss.

Since the cubic covariant of the binary cubic is the evectant of its discriminant, it follows easily that the cubic covariant plane is the polar plane of the point O with regard to the developable.

By taking the polar plane of a point on the line OO' we find it to be of the form

$$\lambda^3 Q + \lambda^2\mu q + \lambda\mu^2 k + \mu^3 K = 0.$$

Hence we have two new planes, q and k, giving rise to two cubic covariants in the binary system, the leading terms of which are

$$qo = a_0\frac{dQ}{da_0} + a_1\frac{dQ}{da_1} + a_2\frac{dQ_0}{da^2} + a_3\frac{dQ_0}{da_3},$$

$$k_0 = a_0\frac{dK_0}{da_0} + a_1\frac{dK_0}{da_1} + a_2\frac{dK_0}{da_2} + a_3\frac{dK}{da_3},$$

where

$$\begin{aligned} \phi_0 &= a_0^2a_3 - 3a_0a_1a_2 + 2a_1^3, \\ K_0 &= a_0^2a_3 - 3a_0a_1a_2 + 2a_1^3. \end{aligned}$$

Now it is easy to show that

$$q_0 = 3\{a_0(a_0a_3 - a_1a_2) - 2a_1(a_0a_2 - a_1^2)\} + \{a_0a_3 - a_3a_0 - 3(a_1a_2 - a_1a_2)\}a_0$$

$$= 6\{a_0\Delta_1 - a_1\Delta_0\} + (aa)^3a_0 :$$

hence

$$q_x = 6(a\Delta)a_x^2\Delta_x + (aa)^3b_x^3.$$

And in the same way

$$k_x = 6(a\nabla)a_x^2\nabla_x - (aa)^3\beta_x^3.$$

We have now expressed q and k in terms of Clebsch's forms, and can represent them as follows:—The covariant q_x^3 is transformed into a plane which is the polar plane of O' with regard to the polar quadric of O.

In like manner k_x^3 is transformed into a plane which is the polar plane of O with regard to the polar quadric of O'. These theorems are immediate algebraic consequences of the method of generation of the covariants q and k.

VII.

We now discuss Clebsch's two linear covariants p_x and π_x.

If through a point X, Y, Z, W, and two points on the curve, the parameters of which are given by the equation

$$\Delta_x^2 = \Delta_0x_1^2 + 2\Delta_1x_1x_2 + \Delta_2x_2^2 = 0,$$

we draw a plane, it will meet the curve in a third point determined by the equation

$$x_1\{\Delta_0Y + 2\Delta_1Z + \Delta_2W\} + x_2\{\Delta_0X + 2\Delta_1Y + \Delta_2Z\} = 0.$$

And if we suppose that Δ is the Hessian of f, and that the point X, Y, Z, W is the corresponding point O' of the plane ϕ, we find the above equation becomes

$$(\Delta a)^2a_x = 0, \text{ or } p_x = 0.$$

Hence the linear covariant p_x is represented by the point in which a plane through O', and containing the chord through O, meets the curve, a similar construction representing π_x, where $\pi_x = (\Delta a)^2a_x$.

VIII.

We now turn to the quadratic covariants. The equation determining the parameters of the points in which a chord through any point on the line OO' is

$$\lambda^2\Delta_x^2 + 2\lambda\mu\Theta_x^2 + \mu^2\nabla_x^2 = 0.$$

The forms Δ and ∇ have been discussed before, and it remains to attach a geometrical meaning to $\Theta_x^2 \equiv (a\alpha)^2 a_x a_x$. Now, from any given point on the curve can be drawn two chords which will meet the line OO', the above equation in $\lambda : \mu$ determining the points of meeting on OO'; if, then, the co-efficient of $\lambda\mu$ is zero, the chords drawn from the given point meet the line OO' in two points harmonically conjugate with regard to O and O'.

Hence Θ_x^2 is represented geometrically by the two points on the curve; the chords from which, to meet the line OO', divide it harmonically.

IX.

Let us now determine the tangent lines to the curve which meet a line through X, Y, Z, W, and a point on the curve the parameter of which is $x_1' : x_2'$.

The co-ordinates of a line through X, Y, Z, W, and a point $x_1' : x_2'$ on the curve, are

$$\begin{aligned} a &= x_1'^2 x_2' Z - x_1 x_2'^2 Y, & f &= x_1'^3 W - X x_2'^3, \\ b &= x_1' x_2'^2 X - x_1'^3 Z, & g &= x'^2 x_2' W - X x_3'^3, \\ c &= x_1'^3 Y - x_1'^2 x_2 X, & h &= x_1' x_2'^2 W - Z x_2'^3, \end{aligned}$$

forming the condition that this line may meet a tangent line, the co-ordinates of which are given by ∇., and dividing by a factor

$$(x_1 x_2' - x_2 x_1')^2,$$

we find

$$x_1^2 (W x_1' - Z x_2') + 2 x_1 x_2 (Y x_2' - Z x_1') + (Y x_1' - X x_2') x^2{}_2 = 0.$$

Suppose now the point X, Y, Z, W to be the point O, and the point on the curve, the point p_x or $(\Delta\alpha)^2 a_x$, the above equation becomes

$$x_1^2 . (a_0 x' + a_1 x_2') + 2 x_1 x_2 . (a_1 x_1' + a_2 x_3') + (a_2 x_1' + a_3 x_2') x_2^2 = 0;$$

or $(ap) a_x^2 = 0$. We can easily express this in terms of Clebsch's forms as follows:—

$$\Theta_x^2 = (a\alpha)^2 a_x a_x;$$

hence
$$2(\Theta\Delta)\Theta_x = (a\alpha)^2 \{a_x (\alpha\Delta) + \alpha_x (a\Delta)\};$$

therefore
$$2(\Theta\Delta)\Theta_x \Delta_x = a_x (\alpha\Delta)(a\alpha)(a\alpha)\Delta_x + (a\alpha)^2 (a\Delta)\alpha_x \Delta_x =$$

$$a_x (a\alpha)(\alpha\Delta)\{a_x (\Delta\alpha) + \alpha_x (a\Delta)\} + (a\alpha)^2 (a\Delta)\alpha_x \Delta_x$$

$$= -a_x^2 (a\alpha)(\Delta\alpha)^2. \quad \text{(See Clebsch, § 34.)}$$

Hence
$$(pa) a_x^2 = 2(\Theta\Delta)\Theta_x \Delta_x.$$

The three remaining quadratic covariants are constructed as follows:—

Through O and the point p on the curve draw a line; then the two points on the curve, the tangents at which meet this line, represent the quadratic covariant $(\Theta\Delta)\Delta_x\Theta_x$. In the same manner the covariant $(\Theta\nabla)\Theta_x\nabla_x$ is represented, while $(\Delta\nabla)\Delta_x\nabla_x$ is represented by the points, the tangents at which meet the line $O\pi$ or the line $O'p$.

X.

We shall now discuss the six remaining linear covariants.

We saw that the linear covariant obtained by drawing a plane through the corresponding point of a plane resulting from a binary form a_x^3, and two points on the curve given by the equation $\Delta_x^2 = 0$, was $(\Delta a)^2 a_x$. Now, if we substitute K for a, we find $(\Delta K)^2 K_x$, which is Clebsch's form.

To represent the covariant $(\Delta K)^2 K_x$, draw a plane through the chord through O, and passing through K, the corresponding point of the plane K, this plane will meet the curve again in the required point. By a similar construction the covariant $(\nabla Q)^2 Q_x$ is represented.

XI.

We now show how to represent the forms $(\pi\nabla)\nabla_x$ and $(p\Delta)\Delta_x$. We have shown how to construct the two points corresponding to the form $(\Theta\Delta)\Delta_x\Theta_x$, which we shall call for the moment ρ_x^2, and we know (VII.) that the linear covariant derived by drawing a plane through the two points given by $\rho_x^2 = 0$ and a third point a is $(\rho a)^2 a_x$. Now,

$$\rho_x^2 = (\Theta\Delta)\Theta_x\Delta_x;$$

therefore $$(\rho a)^2 = (\Theta\Delta)(\Theta a)(\Delta a);$$

but $$(a\Delta)a_y a_x \Delta_y = (a\Delta)a_y^2\Delta_x;$$

therefore $$(\rho a)^2 a_x = (a\Delta)(a\Theta)^2\Delta_x.$$

Now, $$p_x = -2(\Theta a)^2 a_x;$$

therefore $$(p\Delta)\Delta_x = -2(\Theta a)^2(a\Delta)\Delta;$$

therefore $$(\rho a)^2 a_x = -\tfrac{1}{2}(p\Delta)\Delta_x.$$

Hence draw a plane through O and the two points given by the equation $(Q\Delta)\Delta_x Q_x = 0$, which will meet the curve in a third point representing the linear covariant $(p\Delta)\Delta_x$.

In the same way the form $(\pi\nabla)\nabla_x$ is represented.

XII.

The two remaining linear covariants may be represented as follows:—Construct the corresponding point of the plane containing the chord through O and the point O'; the plane meets the curve in points given by the equation $\Delta_x^2 p_x = 0$, which we shall call $R_x^3 = \Delta_x^2 p_x$; through the corresponding point of the plane and the chord through O' draw a plane, meeting the curve in a third point given by the equation

$$(R\nabla)^2 R_x = 0.$$

Now $$R_y^3 = \Delta_y^2 p_y;$$

therefore $$3R_y^2 R_x = 2\Delta_y \Delta_x p_y + \Delta_y^2 p_x,$$

or $$3(R\nabla)^2 R_x = 2(\Delta\nabla)\Delta_x(p\nabla) + (\Delta\nabla)^2 p_x,$$

which expresses $(R\nabla)^2 R_x$ in terms of Clebsch's forms.

In the same way we can represent the form

$$2(\pi\nabla)(\Delta\nabla)\nabla_x + (\nabla\Delta)^2 \pi_x.$$

XIII.

We now turn to the invariants, of which there are seven, two being combinative.

Let us seek the condition that the point O may lie in the plane ϕ, and we know, by what we have proved in I., that when this condition is fulfilled, O' lies in the plane f.

Expressing the condition that the point $a_3, -a_2, a_1, -a_0$ may lie in the plane $$a_0 X + 3a_1 Y + 3a_2 Z + a_3 W = 0,$$

we find $$(aa)^3 = 0, \text{ or } J = 0.$$

Hence J vanishes when O lies in the plane of ϕ; but in this case the line f, ϕ, becomes identical with its corresponding line, and this relation is evidently combinative, since it depends only on the line f, ϕ.

$\Omega = 0$ is the condition that must be satisfied in order that $f + k\phi$ may become a perfect cube; hence, when it vanishes it will be possible to draw an osculating plane through the line f, ϕ, and for the same reason as before this relation is combinative. It is easy to see also that when Ω vanishes that the line corresponding to f, ϕ, or the line OO' meets the curve.

Now, Clebsch has shown analytically that $2\Omega = (p\pi)$, and we can show geometrically that when Ω vanishes, or that when the line OO' meets the curve in a point O'', that the points p and π coincide. The point p is the point in which a plane containing O' and the chord through O meets the curve again; but this plane contains the line OO', which, by hypothesis, meets the curve in O''; hence, when $\Omega = 0$, p coincides with O'', and in like manner π is shown to coincide with O'', and therefore with p.

The two discriminants have been discussed before as the conditions that the points O and O' should lie on the developable formed by tangent lines to the curve, respectively.

We now come to the invariants

$$\Sigma = (aK)^3 = (\Theta\nabla)^2,$$
$$S = (aQ)^3 = (\Theta\Delta)^2.$$

Now it is easy to see that Σ is the condition that O should lie in the plane K, or that the line f, K should coincide with its own conjugate. S, in like manner, is the condition that O' should lie in the plane Q.

It remains to discuss the invariant $T=(\Delta\nabla)^2$. The vanishing of this invariant may be geometrically expressed in various ways. When $T=0$, the planes through any chord and the four points in which the chords through O and O' respectively meet the curve, form a harmonic system. Again, when $T=O$, the polar quadric of O passes through O', and *vice versâ*.

In this investigation I have adopted throughout the notation and procedure of Clebsch, which lends itself more readily than other methods to the identification of binary forms with their geometrical significations.

NOTE ADDED IN THE PRESS.

For convenience, I give a list of the invariants and covariants of a system of two cubics, of which there are, according to Clebsch and Gordan, twenty-eight forms in all, and which I discuss geometrically.

Professor Cayley has, however, drawn my attention to the fact that two of the linear covariants (xa^4a^3 and xa^3a^4) of Clebsch and Gordan have been shown to be non-fundamental by Professor Sylvester. See Sylvester's "Tables of the Generating Functions," *American Journal of Mathematics*, t. ii. (1879.)

Table of Covariants and Invariants of a System of Two Cubics.

Seven Invariants—

$$a\alpha\,;\quad a^4,\quad a^3\alpha,\quad a^2\alpha^2,\quad a\alpha^3,\quad \alpha^4:\qquad a^3\alpha^3.$$
$$(a\alpha)^3\,;\ (\Delta\Delta')^2,\ (\Delta\Theta)^2,\ (\Delta\nabla)^2,\ (\nabla\Theta)^2\,(\nabla\nabla')^2,\ (\Theta\Delta)\,(\Theta\nabla)\,(\Delta\nabla).$$

Six Linear Covariants—

$$xa^2\alpha,\quad xa\alpha^2\,;\qquad xa^4\alpha,\qquad xa^3\alpha^2,\quad xa^2\alpha^3,\qquad xa\alpha^4.$$
$$(\Delta a)^2a_x,\ (\nabla a)^2a_x\,;\ (a\Delta)^2\,(a\Delta')\,\Delta'_x,\ (Q\nabla)^2\,Q_x\,(K\nabla)^2K_x,\ (a\nabla)^2\,(a\nabla')\,\nabla_x'.$$

Six Quadratic Covariants—

$$x^2a^2,\ x^2a\alpha,\ x^2\alpha^2,\quad x^2a^3\alpha,\qquad x^2a^2\alpha^2,\qquad x^2a\alpha^3,$$
$$\Delta_x^2,\quad \Theta_x^2,\quad \nabla_x^2\,(\Delta\Theta)\Delta_x\Theta_x,\ (\Delta\nabla)\Delta_x\nabla_x,\ (\nabla\Theta)\nabla_x'\Theta_x.$$

Six Cubic Covariants—

$$x^3a,\ x^3\alpha,\ x^3a^3,\quad x^3a^2\alpha,\qquad x^3a\alpha^2,\quad x^3\alpha^3.$$
$$a_x^3,\quad \alpha_x^3,\quad Q_x^3,\quad (\Delta\alpha)\Delta_x a_x^2,\ (\nabla a)\nabla_x a_x^2,\quad K_x^3.$$

One Quartic Covariant—

$$x^4a\alpha.$$
$$(a\alpha)a_x^2\alpha_x^2.$$

In this Table I have identified, at the suggestion of Professor Cayley, the Covariants given by Sylvester, with the notation of Clebsch and Gordan.

LXXIV.—Report on the Botany of the Mountainous portion of Co. Fermanagh to the west of Lough Erne, and the adjoining district of Co. Cavan. By Samuel Alexander Stewart, Fellow of the Botanical Society of Edinburgh, Curator of the Collections in the Museum of the Belfast Natural History and Philosophical Society.

[Read, February 27, 1882.]

The region to which this Report has reference is included in two counties, Cavan and Fermanagh, and lies near the western extremity of District X. of the "Cybele Hibernica." That portion of Fermanagh situated near the western and south-western boundaries of the county possesses a more diversified surface than the eastern portion, and the numerous ranges of hills attain a much higher elevation. Even here, however, except where it adjoins Cavan, it can scarcely be called mountainous, but rather hilly and rocky. At Drumbad, near Lough Melvin, on the extreme west of Fermanagh, there is an elevated plateau, extending for several miles, where the hill-tops rise, in places, to over 1000 feet. This is the northern end of a system of hills and highlands that stretches southwards to Lough Macnean, and the borders of county Cavan, culminating in Belmore Mountain, near Belcoo. Belmore has an altitude of 1312 feet, while several other summits, at this end of the range, attain to heights of 1000 to 1200 feet. On passing over the boundary, and entering the north-west side of Cavan, the country becomes more decidedly mountainous; several summits approach 2000 feet, and Cuilceagh exceeds that altitude. The rock strata consist, at the lower levels, of carboniferous limestone, rising to somewhere about 1000 feet; the rock being, in many places, exposed in low cliffs and crags, which often impart a picturesque aspect to scenery otherwise tame. Superimposed on these rocks we find, at higher elevations, thin beds of black shale, capped by massive, thick-bedded, sandstones and grits, forming a series of bare, bleak, uninviting mountains, unproductive alike to the botanist and the agriculturist.

Though the Shannon has here its origin, yet there is no river of any magnitude flowing through the district; but many small lakes lie in rocky hollows amongst the hills, while more extensive sheets of water stud the surface of the level country in all directions. It will be observed that the number of plants in the present list is not very large, a result which is due to several causes. The district being altogether inland, plants of the seashore, and those that prefer the proximity of the coast, are absent. The number is still further

restricted by the nature of the ground over which my observations extended, which is almost entirely heathy and rocky, agricultural weeds being thereby, to a great extent, excluded. Nevertheless, there still remains the fact that a great degree of sameness was found to characterize the vegetation all over these mountains, and that the plants which have, in Britain, the widest range immensely preponderate. This will be shown if we analyze the list which follows, and compare its constituents with the entire Irish flora, as given in the "Cybele Hibernica." For the sake of clearness I shall, in stating the proportions as regards the prevalence of the several British types, disregard fractions; such a degree of exactness not being essential, seeing that there is often a doubt as to which type a plant should be referred. The Irish flora contains representatives of each of Watson's types of British vegetation, with the addition of a "Hibernian type," or a group of plants which do not occur in Great Britain. None of this latter group are included in my enumeration, and plants of Watson's "Germanic type" are also entirely absent. The "Atlantic type" forms four per cent. of the Irish flora, but only one per cent. of those on my list. Plants included in the "Highland type" make five per cent. of the species given in the "Cybele Hibernica," but only two per cent. of those in our district. Plants of the "Scottish type" constitute seven per cent. of Irish plants, but three per cent. only of this catalogue. The "English type" claims about twenty-four per cent. of the entire Irish flora, but only five per cent. of those in our limited area. The *Leguminosæ* and *Labiatæ* are especially strong in plants of the English type, but the paucity in this district of plants of these orders is apparent on reference to the subjoined list. Lastly, the "British type" of Watson, which includes the species most widely spread, and usually the most abundant, supplies about fifty-eight per cent. in number of the plants of Ireland, but gives a proportion of eighty-nine per cent. as regards this mountain district of Fermanagh and Cavan.

A very few plants which flower in early spring were not seen by me, and a few others could, no doubt, be added by any botanist having more protracted opportunities for the search; but the enumeration here given may be taken as substantially the flora of the district to which it refers. The only certain addition to the Irish flora, here recorded, is *Potamogeton zizii* (Roth), which I found, in small quantity only, in county Fermanagh. I have no doubt, however, but that this segregate will be found in other parts of the country, when carefully looked for. Professor Babington thinks that a bramble which I found in Fermanagh belongs to *Rubus emersistylus* (Mull.) = *R. briggsii* (Blox.) As the specimens gathered are rather scanty, and as Professor Babington does not speak with absolute certainty, there must still remain some doubt as regards this form. As this is an interesting plant, not previously recognized in Ireland, it is worthy of attention.

The following plants are additions to the flora of District X., not being recorded for that district in the "Cybele Hibernica," nor in the Supplement published by Mr. A. G. More, in 1872 :—

Arabis hirsuta.
Sagina nodosa.
Linum catharticum.
Agrimonia eupatoria.
Rubus emersistylus.
Rosa arvensis.
Antennaria dioica.
Arctium nemorosum.
Hieracium anglicum.
H. lasiophyllum.
Gentiana campestris.
Myosotis cæspitosa.
Callitriche hamulata.
Habenaria viridis.
H. chlorantha.
Potamogeton zizii.
P. pectinatus.
Scirpus setaceous.
Phleum pratense.
Aira flexuosa.
Cystopteris dentata.
Chara aspera.

LIST OF SPECIES.

Ranunculaceæ.

Anemone nemorosa (Linn.)—Cavan and Fermanagh. Shady places in the hills.

Ranunculus flammula (Linn.)—Cavan and Fermanagh. Not at all abundant.

R. ficaria (Linn.)—Cavan and Fermanagh. Common in damp shady places.

R. acris (Linn.)—Cavan and Fermanagh. Common, and sometimes very luxuriant.

R. bulbosus (Linn.)—Knockmore, Co. Fermanagh. Not very common. Note.—I met with none of the Batrachian Ranunculi.

Caltha palustris (Linn.)—Cavan and Fermanagh. Frequent in wet fields and marshes.

Nymphaeaceæ.

Nymphæa alba (Linn.)—Cavan and Fermanagh. Frequent.

Nuphar lutea (Linn.)—Cavan and Fermanagh. Frequent; the two water-lilies seem to be about equally abundant.

Cruciferæ.

Nasturtium officinale (R. Br.)—Cavan and Fermanagh. Common in ditches and slow streams.

Arabis hirsuta (R. Br.)—Very sparingly on the limestone cliffs at Knockmore, Co. Fermanagh.

Cardamine hirsuta (Linn.)—Cavan and Fermanagh. On walls and waste ground.

C. sylvatica (Link.)—Cavan and Fermanagh. Damp shady rocks.

C. pratensis (Linn.)—Frequent in Cavan and Fermanagh. Meadows and damp pastures.

Sisymbrium officinale (Scop.)—Cavan and Fermanagh. Roadsides and waste places.
Alliaria officinalis (Andrz.)—Co. Fermanagh. Occurs on limestone rocks at Knockmore, and occasionally on hedge banks.
Sinapis arvensis (Linn.)—Cavan and Fermanagh. Fields and waste places.
Capsella bursa-pastoris (D.C.)—Cavan and Fermanagh. Hedge banks and waste ground.

Violaceæ.

Viola palustris (Linn.)—Frequent in Cavan and Fermanagh. Boggy ground in the hills.
V. sylvatica (Fries.)—Cavan and Fermanagh. Common.

Droseraceæ.

Drosera rotundifolia (Linn.)—Cavan and Fermanagh. Frequent in peat bogs.
D. anglica (Huds.)—Legland Mountain, Co. Fermanagh. Rare.
Parnassia palustris (Linn.)—Knockmore and Carrick, Co. Fermanagh—Local. Wet rocky places.

Polygalaceæ.

Polygala vulgaris (Linn.)—Cavan and Fermanagh. Common on heaths and dry hilly pastures.

Caryophyllaceæ.

Lychnis flos-cuculi (Linn.)—Cavan and Fermanagh. Meadows and damp pastures.
L. diurna (Sibth.)—Knockmore, Co. Fermanagh. Scarce, dry shaded rocks.
Sagina procumbens (Linn.)—Cavan and Fermanagh. Damp waste ground.
S. nodosa (E. Meyer.)—Co. Fermanagh. Rare; sparingly by the margin of Lough Navar, Drumbad.
Stellaria media (Linn.)—Common everywhere.
S. holostea (Linn.)—Shady rocks at Knockmore; perhaps common.
S. graminea (Linn.)—Not uncommon in Cavan and Fermanagh; seen occasionally.
Cerastium glomeratum (Thuil.)—Very abundant, especially on the limestone in Cavan and Fermanagh.
C. triviale (Link.)—Common in Cavan and Fermanagh, but less abundant than the preceding species.
Spergula arvensis (Linn.)—Common in fields.

HYPERICACEÆ.

Hypericum androsæmum (Linn.)—Marble Arch, &c., Co. Fermanagh. Not common.
H. perforatum (Linn.)—Carrick, Co. Fermanagh. Not common.
H. pulchrum (Linn.)—Cavan and Fermanagh. Common on heaths and dry banks.

GERANIACEÆ.

Geranium molle (Linn.)—Frequent in Cavan and Fermanagh.
G. lucidum (Linn.)—Frequent on the limestone rocks in Cavan and Fermanagh.
G. Robertianum (Linn.)—Cavan and Fermanagh. Common.

OXALIDACEÆ.

Oxalis acetosella (Linn.)—Common everywhere.

LINACEÆ.

Linum catharticum (Linn.)—Cavan and Fermanagh. Common.

LEGUMINOSÆ.

Ulex europæus (Linn.)—Cavan and Fermanagh. But not at all abundant.
Trifolium pratense (Linn.)—Cavan and Fermanagh. Common.
T. repens (Linn.)—Common everywhere.
T. minus (Sm.)—Common.
Lotus corniculatus (Linn.)—Common in Cavan and Fermanagh.
Anthyllis vulneraria (Linn.)—Knockmore, Carrick, &c. Frequent on the limestone rocks.
Vicia cracca (Linn.)—Common on hedge banks.
V. sepium (Linn.)—Cavan and Fermanagh. Frequent.
Lathyrus pratensis (Linn.)—Cavan and Fermanagh. But not at all abundant.

ROSACEÆ.

Prunus spinosa (Linn.)—Common everywhere.
Spiræa ulmaria (Linn.)—Frequent througout the district.
Agrimonia eupatoria (Linn.)—On limestone rocks at Knockmore, Carrick, &c.; but not common.
Alchemilla vulgaris (Linn.)—Cavan and Fermanagh. Frequent.
A. arvensis (Linn.)—Cavan and Fermanagh. Not uncommon in cultivated ground.
Potentilla anserina (Linn.)—Cavan and Fermanagh. But not abundant.
P. tormentilla (Nesl.)—Everywhere abundant.
P. fragariastrum (Ehr.)—Cavan and Fermanagh. Frequent.
Fragaria vesca (Linn.)—Common on the hills.

Rubus idæus (Linn.)—Limestone rocks at Knockmore; but not common.
R. discolor (W. and N.)—Abundant. This is the common bramble of the district.
R. koehleri (Weihe.)—Frequent throughout the district.
R. emersistylus (Müll.)=*R. briggsii* (Blox.)—Specimens which I gathered near Derrygonnelly, Co. Fermanagh, were submitted by my friend Mr. T. H. Corry, M.R.I.A., &c., to Professor Babington, who kindly examined them, and, as the result of his diagnosis, informs us that he thinks them to belong to *R. briggsii*. It is unfortunate that a suite of specimens sufficient to place the species beyond doubt was not collected. Brambles are sufficiently abundant in the district, but with less than the usual diversity of forms.
Dryas octopetala (Linn.)—Abundant in one spot on the summit of the limestone cliffs of Knockmore, at the western end. This plant is evidently the var. a., and is the same form as that which occurs on Ben Bulben, having the sepals beset with red glandular hairs.
Geum urbanum (Linn.)—Cavan and Fermanagh. Hedge banks; but not abundant.
G. rivale (Linn.)—Cavan and Fermanagh. Frequent on margins of streams.
Rosa tomentosa (Sm.)—Cavan and Fermanagh. Common.
R. canina (Linn.)—Cavan and Fermanagh. Common.
R. arvensis (Huds.)—Co. Fermanagh. Sparingly near Florence Court, on old road leading to Swanlinbar.
Cratægus oxyacantha (Linn.)—Cavan and Fermanagh. Common.
Pyrus aucuparia (Gaert.)—Carrick and Drumbad, Co. Fermanagh.

ONAGRACEÆ.

Epilobium parviflorum (Schreb.)—Cavan and Fermanagh. Common.
E. montanum (Linn.)—Cavan and Fermanagh. But less plentifully than the preceding species.
Circæa lutetiana (Linn.)—Marble Arch, &c., Co. Fermanagh.

HALORAGACEÆ.

Myriophyllum alterniflorum (D. C.)—Carrick Lake, Co. Fermanagh.

PORTULACEÆ.

Montia fontana (Linn.)—Cavan and Fermanagh. Frequent in wet stony places.

CRASSULACEÆ.

Cotyledon umbilicus (D.C.)—Co. Fermanagh. On rocks at Carrick.

SAXIFRAGACEÆ.

Saxifraga hypnoides (Linn.)—Knockmore, Co. Fermanagh.
Chrysosplenium oppositifolium (Linn.)—Cavan and Fermanagh. Frequent on wet rocks.

Umbelliferæ.

Sanicula europæa (Linn.)—Cavan and Fermanagh. Knockmore, Carrick, &c.
Helosciadum nodiflorum (Koch.)—Cavan and Fermanagh. Frequent.
Ægopodium podagraria (Linn.)—Cavan and Fermanagh. Common.
Bunium flexuosum (With.)—Cavan and Fermanagh. Knockmore, &c.
Œnanthe phellandrium (Lam.)—Co. Fermanagh. Slow stream at west end of Carrick Lake.
Heracleum sphondylium (Linn.)—Cavan and Fermanagh. Common on waste ground.
Torilis anthriscus (Gaert.)—Cavan and Fermanagh. Everywhere abundant.
Anthriscus sylvestris (Hoffm.)—Frequent in Cavan and Fermanagh, but much less abundant than the preceding.

Hederaceæ.

Hedera helix (Linn.)—Cavan and Fermanagh. Common.

Caprifoliaceæ.

Viburnum opulus (Linn.)—Carrick, &c. Frequent in Co. Fermanagh.
Lonicera periclymenum (Linn.)—Cavan and Fermanagh. Common.

Rubiaceæ.

Asperula odorata (Linn.)—Cavan and Fermanagh. Shady places, but not abundant.
Galium aparine (Linn.)—Cavan and Fermanagh. Very common.
G. verum (Linn.)—Cavan and Fermanagh. Common.
G. saxatile (Linn.)—Cavan and Fermanagh. Common on the hills.
G. palustre (Linn.)—Wet places. Common in Cavan and Fermanagh.

Valerianaceæ.

Valeriana officinalis (Linn.)—Carrick, &c. Frequent in Cavan and Fermanagh.

Dipsaceæ.

Scabiosa succisa (Linn.)—Cavan and Fermanagh. Common.

Compositæ.

Tussilago farfara (Linn.)—Cavan and Fermanagh. Frequent.
Bellis perennis (Linn.)—Common everywhere.
Solidago virgaurea (Linn.)—Co. Fermanagh. Carrick, Knockmore, Tents Mountain, &c. Not common.
Achillea millefolium (Linn.)—Cavan and Fermanagh. Frequent.
Chrysanthemum leucanthemum (Linn.)—In the utmost profusion everywhere.

Chrysanthemum segetum (Linn.)—Cavan and Fermanagh. Common in cultivated ground.
Antennaria dioica (Gaert.)—Cavan and Fermanagh. Grassy spots, Knockmore, Carrick, &c.
Senecio vulgaris (Linn.)—Common everywhere.
S. sylvaticus (Linn.)—Near Florence Court, Co. Fermanagh.
S. Jacobæa (Linn.)—Common everywhere.
S. aquaticus (Huds.)—Cavan and Fermanagh. Frequent.
Arctium nemorosum (Lej.)—On limestone rocks at Knockmore, Co. Fermanagh. Professor Babington, who kindly diagnosed my specimen, confirms the name.
Centaurea nigra (Linn.)—Common in Cavan and Fermanagh.
Carduus lanceolatus (Linn.)—Common everywhere.
C. arvensis (Curt.)—Cavan and Fermanagh; but less common than I have usually found it elsewhere.
C. palustris (Linn.)—Cavan and Fermanagh. Common.
C. pratensis (Huds.)—Cavan and Fermanagh. Frequent in damp pastures and meadows.
Lapsana communis (Linn.)—Cavan and Fermanagh. Common.
Hypochæris radicata (Linn.)—Roadsides and waste places. Common everywhere.
Apargia autumnalis (Willd.)—Carrick, Drumbad, &c. Frequent in Cavan and Fermanagh.
Leontodon taraxicum (Linn.)—Cavan and Fermanagh. Common everywhere.
Sonchus oleraceus (Linn.)—Cavan and Fermanagh. Roadsides and banks.
S. arvensis (Linn.)—Cavan and Fermanagh. Cultivated fields.
Crepis paludosa (Moench.)—Very common in Cavan and Fermanagh. It seems to replace *C. virens*, which I did not see.
Hieracium pilosella (Linn.)—Cavan and Fermanagh. Common.
H. anglicum (Fries.)—Cavan and Fermanagh. It occurs plentifully on limestone cliffs at Knockmore, and is found in more or less abundance at Carrick, Drumbad, Tents Mountain, and Cuilceagh.
H. cinerascens (Jord.) = *H. lasiophyllum* (Bab.)—Knockmore, Carrick and Badmore, Co. Fermanagh, but only in very small quantity. By the kindness of Mr. Backhouse, who examined my specimens of this and the preceding species, I am enabled to publish these names with certainty.

Campanulaceæ.

Campanula rotundifolia (Linn.)—Cavan and Fermanagh. Frequent.

Ericaceæ.

Calluna vulgaris (Salisb.)—Common on the hills.
Erica tetralix (Linn.)—Common on heaths.

Erica cinerea (Linn.) Common.
Vaccinium myrtillus (Linn.)—Cavan and Fermanagh. Common on the hills.
V. vitis-idæa (Linn.)—Cavan and Fermanagh. Occurs on Drumbad, Tents Mountain, Cuilceagh, and adjoining mountains; often in some quantity.

AQUIFOLIACEÆ.

Ilex aquifolium (Linn.)—Cavan and Fermanagh. Common on the rocks.

GENTIANACEÆ.

Erythræa centaurium. (Pers.)—Cavan and Fermanagh. Frequent on short dry pastures.
Gentiana campestris (Linn.)—Co. Fermanagh. Sparingly on Legland Mountain, near Derrygonnelly.
Menyanthes trifoliata (Linn.)—Cavan and Fermanagh. Boggy places on the hills.

BORAGINACEÆ.

Myosotis cæspitosa (Schultz.)—Co. Fermanagh. Marshes and sides of streams occasionally, Carrick, &c.
M. arvensis (Lehm.)—Cavan and Fermanagh. Common.
M. versicolor (Reich.)—Cavan and Fermanagh. Common on dry banks, and waste places.

SCROPHULARIACEÆ.

Digitalis purpurea (Linn.)—Cavan and Fermanagh. But not abundant.
Scrophularia nodosa (Linn.)—Derrygonnelly, &c., Co. Fermanagh. But not common.
Melampyrum pratense (Linn.)—Cavan and Fermanagh. Common in shady places.
Pedicularis palustris (Linn.)—Cavan and Fermanagh. Marshes in the hills.
P. sylvatica (Linn.)—Cavan and Fermanagh. Abundant on the hills.
Rhinanthus crista-galli (Linn.)—Common everywhere.
Euphrasia officinalis (Linn.)—Cavan and Fermanagh. Common.
Veronica beccabunga (Linn.)—Cavan and Fermanagh. Wet places; frequent.
V. chamædrys (Linn.)—Everywhere abundant.
V. officinalis (Linn.)—Cavan and Fermanagh. Common.
V. serpyllifolia (Linn.)—Everywhere common.
V. agrestis (Linn.)—Cavan and Fermanagh. Borders of fields; common.

LABIATÆ.

Mentha aquatica (Linn.)—Wet places; common.
M. sativa (Linn.)—Cavan and Fermanagh. Fields and waste ground; common.

Thymus serpyllum (Linn.)—On the hills; common.
Prunella vulgaris (Linn.)—Everywhere common.
Nepeta glechoma (Benth.)—Cavan and Fermanagh. Frequent on hedge banks.
Lamium purpureum (Linn.)—Cavan and Fermanagh. Waste places; common.
Galeopsis tetrahit (Linn.)—Cavan and Fermanagh. Frequent.
Stachys sylvatica (Linn.)—Cavan and Fermanagh. Shady places; common.
S. palustris (Linn.)—Cavan and Fermanagh. Common in damp places.
Ajuga reptans (Linn.)—Everywhere common.

LENTIBULARIACEÆ.

Pinguicula vulgaris (Linn.)—Cavan and Fermanagh. Wet places on the hills.

PRIMULACEÆ.

Primula vulgaris (Huds.)—Common everywhere.
Lysimachia nemorum (Linn.)—Cavan and Fermanagh. Frequent.
Anagallis arvensis (Linn.)—Fields and waste ground; common.
A. tenella (Linn.)—Boggy ground, Drumbad, Co. Fermanagh, with white flowers; rare.

PLANTAGINACEÆ.

Plantago lanceolata (Linn.)—Hedge banks and pastures; common.
P. major (Linn.)—Roadsides and wastes; common.
Littorella lacustris (Linn.)—Margin of Carrick Lake, Co. Fermanagh. Not at all common.

POLYGONACEÆ.

Rumex conglomeratus (Murr.)—Cavan and Fermanagh. Roadsides and banks.
R. obtusifolius (Linn.)—Roadsides and waste ground; common.
R. crispus (Linn.)—Cavan and Fermanagh. Frequent.
R. acetosa (Linn.)—Cavan and Fermanagh. Hedge banks, &c.
R. acetosella (Linn.)—Mountain pastures; common.
Polygonum persicaria (Linn.)—Cavan and Fermanagh. Damp fields and wastes.
P. hydropiper (Linn.)—Cavan and Fermanagh. Banks of streams and wet places.
P. aviculare (Linn.)—Waste ground; common everywhere.

EMPETRACEÆ.

Empetrum nigrum (Linn.)—Legland Mountain, near Derrygonnelly, Co. Fermanagh.

EUPHORBIACEÆ.

Euphorbia helioscopia (Linn.)—Frequent in cultivated fields.
E. peplus (Linn.)—Cavan and Fermanagh. Frequent.

CALLITRICHACEÆ.

Callitriche verna (Linn.)—Carrick, &c. In streams.
C. hamulata (Kutz.)—Very luxuriant at Carrick, Co. Fermanagh.

URTICACEÆ.

Urtica dioica (Linn.)—Everywhere common.

AMENTIFERÆ.

Salix pentandra (Linn.)—Derrygonnelly and Carrick, Co. Fermanagh.
S. cinerea (Linn.)—Cavan and Fermanagh. Common.
S. aurita (Linn.)—Hilly places; frequent.
Myrica gale (Linn.)—Heaths and bogs; frequent.
Alnus glutinosa (Gaert.)—Cavan and Fermanagh. Common.
Corylus avellana (Linn.)—Hedges and glens; common everywhere.

CONIFERÆ.

Taxus baccata (Linn.)—Sparingly on limestone cliffs at Carrick, and Knockmore, Co. Fermanagh.

ORCHIDACEÆ.

Orchis mascula (Linn.)—Damp pastures; common.
O. maculata (Linn)—Meadows and damp ground; common.
Habenaria viridis (R. Br.)—Legland Mountain, Co. Fermanagh; sparingly.
H. chlorantha (Bab.)—Cavan and Fermanagh, Carrick, &c. Frequent.
Listera ovata (R. Br.)—Everywhere abundant, especially on the limestone.

IRIDACEÆ.

Iris pseud-acorus (Linn.)—Cavan and Fermanagh. Common.

LILIACEÆ.

Endymion nutans (Dum.)—Cavan and Fermanagh. Shady banks.

JUNCACEÆ.

Narthecium ossifragum (Huds.)—Cavan and Fermanagh. Frequent on heaths.
Juncus effusus (Linn.)—Everywhere common.
J. conglomeratus (Linn.)—Cavan and Fermanagh. Common.

Juncus glaucus (Ehr.)—Cavan and Fermanagh. Frequent.
J. acutiflorus (Ehr.)—In marshy places throughout the district.
J. squarrosus (Linn.)—Mountain heaths; common.
Luzula sylvatica (Bich.)—Cavan and Fermanagh. Not uncommon.
L. campestris (Willd.)—Cavan and Fermanagh. Frequent.

ALISMACEÆ.

Alisma plantago (Linn.)—Cavan and Fermanagh. Occurs occasionally.

TYPHACEÆ.

Triglochin palustre (Linn.)—Cavan and Fermanagh. In wet places at Carrick, &c.

ARACEÆ.

Arum maculatum (Linn.)—Cavan and Fermanagh. Common.

LEMNACEÆ.

Lemna minor (Linn.)—Cavan and Fermanagh. Common.

POTAMOGETONACEÆ.

Potamogeton natans (Linn.)—Lakes and ponds; frequent.
P. rufescens (Schrad.)—Carrick Lake, Co. Fermanagh; rare.
P. zizii—Very sparingly in slow stream which connects Carrick Lake with Bunnahone Lake, near Derrygonnelly, Co. Fermanagh. I am obliged to Mr. Bennett, of Croydon, who pointed out that my plant agrees in all respects with Roth's plant; a judgment since confirmed by Professor Babington.
P. pectinatus (Linn.)—Carrick Lake, Co. Fermanagh. Not common.

CYPERACEÆ.

Eleocharis palustris (R. Br.)—Common everywhere.
Scirpus lacustris (Linn.)—Cavan and Fermanagh. In the lakes; frequent.
S. cæspitosus (Linn.)—Common on the mountains.
S. setaceous (Linn.)—Drumbad, Co. Fermanagh. Not common.
Eriophorum angustifolium (Roth.)—Bogs and heaths; common.
Carex pulicaris (Linn.)—Knockmore, &c.; not very common.
C. stellulata (Good.)—Cavan and Fermanagh. Common on grassy heaths.
C. remota (Linn.)—Marble Arch, Co. Fermanagh. Not common.
C. ovalis (Good.)—Cavan and Fermanagh. Frequent.
C. vulgaris (Fries.)—Cavan and Fermanagh. Common.
C. pallescens (Lam.)—On Cuilcagh, Binaghlin, and neighbouring mountains, up to 1200 feet; but not common.
C. panicea (Linn.)—Cavan and Fermanagh. Frequent.
C. pendula (Huds.)—Marble Arch, Co. Fermanagh. Very rare.

C. pilulifera (Linn.)—Cavan and Fermanagh. Mountain heaths; rather rare.
C. glauca (Scop.)—Everywhere common.
C. flava (Linn.)—Cavan and Fermanagh. Common.
C. hornschuchiana (Hoppe.)—Cavan and Fermanagh. Carrick, Cuilceagh, &c.
C. binervis (Sm.)—Cavan and Fermanagh. Frequent on mountain heaths.
C. sylvatica (Huds.)—Marble Arch, &c.; but not very common.
C. hirta (Linn.)—Cavan and Fermanagh. Not uncommon.

GRAMINEÆ.

Phalaris arundinacea (Linn.)—Cavan and Fermanagh. Common.
Anthoxanthum odoratum (Linn.)—Common everywhere.
Phleum pratense (Linn.)—Meadows and margins of fields; common.
Alopecurus pratensis (Linn.)—Marble Arch, &c.; but not at all common.
Nardus stricta (Linn.)—Cavan and Fermanagh. On heaths.
Phragmites communis (Trin.)—Cavan and Fermanagh. Occasionally in ditches and marshes.
Agrostis vulgaris (With.)—Cavan and Fermanagh. Common.
Holcus lanatus (Linn.)—Cavan and Fermanagh. Hedge banks and pastures.
Aira cæspitosa (Linn.)—Cavan and Fermanagh. Shady places; frequent.
A. flexuosa (Linn.)—Cavan and Fermanagh. Very common on heaths.
Arrhenatherum elatius (M. & K.)—Everywhere common.
Triodia decumbens (Beauv.)—Cavan and Fermanagh. Frequent on grassy heaths.
Melica uniflora (Retz.)—Carrick, &c., Co. Fermanagh. Shady rocks.
Molinia cærulea (Moench.)—Cavan and Fermanagh. On heaths; frequent.
Poa annua (Linn.)—Cavan and Fermanagh. Common.
P. trivialis (Linn.)—Common everywhere.
P. pratensis (Linn.)—Frequent throughout the district.
Briza media (Linn.)—Rocks at Carrick, Co. Fermanagh.
Cynosurus cristatus (Linn.)—Common everywhere.
Dactylis glomerata (Linn.)—Roadsides and pastures; everywhere.
Festuca rubra (Linn.)—Cavan and Fermanagh. Common.
F. pratensis (Huds.)—Carrick, &c. Not uncommon.
Serrafalcus mollis (Parl.)—Cavan and Fermanagh. Frequent.
Lolium perenne (Linn.)—Everywhere abundant.
L. italicum (A. Braun.)—Banks and pastures; frequent.

EQUISETACEÆ.

Equisetum arvensis (Linn.)—Abundant everywhere.
E. maximum (Lam.)—Cavan and Fermanagh. Frequent.

E. sylvaticum (Linn.)—Cavan and Fermanagh. Not uncommon.
E. limosum (Linn.)—Abundant everywhere.
E. palustre (Linn.)—Cavan and Fermanagh. Common.

Filices.

Polypodium vulgare (Linn.)—Cavan and Fermanagh. Common.
Lastrea filix-mas (Presl.)—Common everywhere.
L. dilatata (Presl.)—Common everywhere.
L. æmula (Brack.)—Co. Fermanagh, Carrick and Drumbad. Beside rocky banks of streams.
Polystichum aculeatum (Roth.)—Cavan and Fermanagh. Not uncommon on the hills.
P. angulare (Newm.)—Common everywhere.
Cystopteris fragilis (Bernh.)—Cavan and Fermanagh. On damp rocks; common.
——Var. *b. dentata* (Sm.)—Frequent; along with the preceding.
Athyrium filix-fœmina (Roth.)—Cavan and Fermanagh. Frequent.
Asplenium adiantum-nigrum (Linn.)—Cavan and Fermanagh; but not abundant.
A. trichomanes (Linn.)—Everywhere common on shady rocks.
A. ruta-muraria (Linn.)—On walls and dry rocks; abundant everywhere.
Scolopendrum vulgare (Sym.)—Common everywhere.
Blechnum boreale (Sw.)—Common everywhere.
Pteris aquilina (Linn.)—On dry heaths; everywhere.
Hymenophyllum wilsoni (Hook.)—Knockmore, Drumbad, Cuilceagh, &c. Frequent in Cavan and Fermanagh.
Osmunda regalis (Linn.)—Carrick and Drumbad, Co. Fermanagh. Abundant and luxuriant by the streams.

Lycopodiaceæ.

Lycopodium selago (Linn.)—Cavan and Fermanagh. In great profusion on the mountains.
Selaginella spinulosa (A. Br.)—Damp shady rocks, Knockmore, and Drumbad, Co. Fermanagh; sparingly.

Characeæ.

Chara aspera (Willd.)—Carrick Lake, Co. Fermanagh.

LXXV.—Recent Foraminifera of Dublin and Wicklow. By Frederick Pryor Balkwill and Joseph Wright, F.G.S.

[Read, February 27, 1882.]

As the examination of the various gatherings of Foraminifera made last year off the Dublin and Wicklow coasts have not yet been fully completed, the present brief Report is now furnished, pending the detailed results which we hope to have ready for publication next year. The following particulars are given to show what has already been accomplished. Previous to the grant having been given, one of us had made a number of shore gatherings in the vicinity of Dublin, and the list of the Foraminifera found was sent to the Academy at the time. Since then thirty dredgings have been secured—three in Dublin Bay, the remaining twenty-seven off the coast—extending from Ireland's Eye to Bray Head, and as far off land as the Kish and Bray Banks, the deepest parts dredged being off Bray Head in twenty-six to twenty-seven fathoms. We are also indebted to Mr. Stephen Voysey, of "Blanna" fishing smack, for six gatherings taken off Mourne Mountains, off Howth, and off the Isle of Man. The Foraminifera which we have already met with number one hundred and twenty-four species and varieties, or about two-thirds of our British forms. Twelve of these are additions to the Irish Fauna, one (*Nodosaria hispida*) is new to Britain, and two (*Lagena curvilineata* and *Nonionina pauperata*) are new to science. The only other locality in Britain which has yielded so large a number of Rhizopoda is the Estuary of the Dee, a spot which has been most carefully examined by Mr. Siddall and Mrs. Shone, and where even a still greater number of forms have been found. When we consider the short space of time already spent in the examination of this part of our coast, our results are most encouraging, and leave little doubt that a renewed search would still further increase the numbers, and lead to the discovery of other rare forms.

LIST OF FORAMINIFERA.

Cornuspira, Schultze.

foliacea, Phillippi. Very rare.
involvens, Reuss. Rare.

Biloculina, D'Orb.

ringens, Lamk. Frequent.
depressa, D'Orb. Frequent.
elongata, D'Orb. Very rare.

Miliolina, Will.

trigonula, Lamk. Frequent.
tricarinata, D'Orb. Very rare.
oblonga, Montagu. Rare.
Brongniartii, D'Orb. Rare.
seminulum, Linn. Very common.
subrotunda, Montagu. Very common.
secans, D'Orb. Common between tides; rare in dredgings.
bicornis, W. & J. Common.
ferussacii, D'Orb. Frequent.
pulchella, D'Orb. Very rare.
fusca, Brady. Very rare; found only off Ireland's Eye, seven to nine fathoms.

Spiroloculina, D'Orb.

limbata, D'Orb. Very rare.
planulata, Lamk. Very rare.

Hyperammina, Brady.

elongata, Brady. Very rare; found only off Ireland's Eye, seven to nine fathoms.

Psammosphæra, F. E. Schultze.

fusca, Schultze. Very rare.

Reophax, Montfort.

difflugiformis, Brady. Very rare.
fusiformis, Will. Very rare.
scorpiurus, Montf. Very rare.

Haplophragmium, Reuss.

canariense, D'Orb. Common.
glomeratum, Brady. Very rare.
globigeriniforme, P. & J. Frequent.

Ammodiscus, Reuss.

incerta, D'Orb. Very rare.
gordialis, J. & P. Very rare.
Shoneana, Siddall. Very rare; a single specimen only.

Trochammina, P. & J.

squamata, P. & J. Frequent.
inflata, Montagu. Rare.
inflata, var. Very rare.
macrescens, Brady. Very rare; found only off Ireland's Eye, seven to nine fathoms.

Textularia, Defrance.

sagittula, Defrance. Frequent.
agglutinans, D'Orb. Very rare.
globulosa, Ehrenb. Very rare; a single specimen only; off Howth, eighteen fathoms.
difformis, Will. Very rare; found only off Dalkey, fifteen fathoms.

Spiroplecta, Ehrenb.

biformis, P. & J. Very rare; a single specimen only; Dalkey Sound.

Gaudryina, D'Orb.

filiformis, Berthelin. Very rare.

Verneuilina, D'Orb.

polystropha, Reuss. Rare.

Bulimina, D'Orb.

purpoides, D'Orb. Common.
marginata, D'Orb. Rare.
ovata, D'Orb. Frequent.
elegantissima, D'Orb. Frequent.

Virgulina, D'Orb.

Schreibersii, Czjzek. Rare.

Bolivina, D'Orb.

punctata, D'Orb. Frequent.
plicata, D'Orb. Frequent
dilatata, Reuss. Very rare.

Cassidulina, D'Orb.

lævigata, D'Orb. Very rare.
crassa, D'Orb. Rare.
oblonga, D'Orb. Very rare.

Lagena, Walker & Jacob.

sulcata, W. & J. Frequent.
costata, Will. Rare.
Williamsoni, Alcock. Very common.
Lyellii, Seguenza. Very rare.
lævis, Montagu. Common.
gracillima, Seguenza. Very rare.
globosa, Montagu. Frequent.
striata, D'Orb. Rare.

LAGENA—*continued.*

curvilineata, nov. sp. Very rare.
gracilis, Will. Very rare.
striato-punctata, P. & J. Very rare.
semistriata, Will. Common.
aspera, Reuss. Very rare.
hispida, Reuss. Very rare.
caudata, D'Orb. Frequent.
marginata, W. & J. Rare.
var. D'Orbignyana, Sequenza. Common.
var. trigono-marginata, P. & J. Very rare.
var. quadrata, Will. Very rare.
ornata, Will. Very rare.
var. trigono-ornata, Siddall. Very rare.
lucida, Will. Common.
var. (trigono-) oblonga, Sequenza. Very rare.
lagenoides, Will. Very rare.
squamosa, Montagu. Very common.
hexagona, Will. Frequent.

LINGULINA, D'Orb.

carinata, D'Orb. Very rare; a single specimen only.

NODOSARIA, Lamk.

raphanus, Linn. Very rare; a single specimen only.
scalaris, Batsch. Rare.
pyrula, D'Orb. and dentaline variety. Very rare.
hispida, D'Orb. Very rare; a single specimen only. New to Britain.

DENTALINA, D'Orb. Rare.

communis, D'Orb. Rare.
consobrina, D'Orb. Very rare.

VAGINULINA, D'Orb.

legumen, Linn. Very rare.
linearis, Montagu. Very rare.

MARGINULINA, D'Orb.

glabra, D'Orb. Very rare.

CRISTELLARIA, Lamk.

rotulata, Lamk. Very rare.
vortex, F. & M. Very rare; a single specimen only; off Ireland's Eye, seven to nine fathoms.
cultrata, Montfort. Very rare; a single specimen only; off Ireland's Eye, seven to nine fathoms.
crepidula, F. & M. Very rare.

POLYMORPHINA, D'Orb.

lactea, W. & J. Rare.
gibba, D'Orb. and var. æqualis, D'Orb. Common.
oblonga, Will. Rare.
compressa, D'Orb. Frequent.
fusiformis, Rœmer. Very rare.
cylindroides, Rœmer. Very rare.
concava, Will. Very rare.

UVIGERINA, D'Orb.

angulosa, Will. Rare.

SPIRILLINA, Ehrenb.

vivipara, Ehrenb. Very rare.
tuberculata, Brady. Very rare; found only off Ireland's Eye, seven to nine fathoms.

ORBULINA, D'Orb.

universa, D'Orb. Very rare.

GLOBIGERINA, D'Orb.

bulloides, D'Orb. Frequent.
inflata, D'Orb. Very rare.

PULLENIA, P. & J.

sphæroides, D'Orb. Very rare; a single specimen only; off Howth, eleven fathoms.

DISCORBINA, P. & J.

rosacea, D'Orb. Common.
globularis, D'Orb. Very common.
Bertheloti, D'Orb. Very rare.
Wrightii, Brady. Very rare.

PLANORBULINA, D'Orb.

Mediterraneensis, D'Orb. Frequent.

TRUNCATULINA, D'Orb.

lobulata, Walker. Very common.

PULVINULINA, P. & J.

auricula, F. & M. Very vare.
Karsteni, Reuss. Very rare.

Tinoporus, Montfort.

lucidus, Brady. Very rare.
lævis, P. & J. Very rare; a single specimen only; off Ireland's Eye, seven to nine fathoms.

Rotalia, Lamk.

Beccarii, Linn. Common.
nitida, Will. Frequent.

Nonionina, D'Orb.

turgida, Will. Rare.
scapha, F. & M. Very rare; a single specimen only; off Ireland's Eye, seven to nine fathoms.
pauperata, nov. sp. Frequent.
umbilicatula, Montagu. Very rare.
depressula, W. & J. Very common.
stelligera, D'Orb. Rare.

Polystomella, Lamk.

crispa, Linn. Common.
striato-punctata, F. &. M. Very common.

SUPPLEMENTAL NOTE.

Since we sent in our Report to the Academy the following additional Foraminifera have been met with, viz:—*Bulimina subteres*, Brady; *B. aculeata*, D'Orb,; *Dentalina obliqua*, D'Orb.; *D. pauperata*, D'Orb.; *Marginulina raphanus*, D'Orb. ? *Polymorphina spinosa*, D'Orb.; *P. myristiformis*, Will.; and *Discorbina biconcava*, P. & J. Of the one hundred and thirty-two species and varieties of Foraminifera recorded in our Report, all are from off the Dublin and Wicklow coasts, except two forms, viz:—*Nodosaria hispida*, D'Orb., and *Discorbina biconcava*, P. & J., gathered off "Hen and Chicken" rocks, Isle of Man.

NOTE ADDED IN THE PRESS.

Whilst our Report was passing through the Press, the following additional species were found, viz.:—*Miliolina tenuis*, Czjzek; *M. agglutinans*, D'Orb.; *Hauerina*, sp.; *Haplophragmium pseudospiralis*, Will.; *Lagena pulchella*, Brady (trigonal variety).

LXXVI.—On the Constitution of the Native Phosphates of Aluminium. By A. H. Church, M.A., Oxon., Professor of Chemistry in the Royal Academy of Arts.

[Read, February 27, 1882.]

§ I. The mineral phosphates and arseniates constitute a very interesting group. The number of species is increased year by year through new discoveries; but the older members of the group are rarely made the subjects of fresh investigation by modern methods. In many instances the constitution of even the more abundant species remains obscure. The frequent presence of an excess of base over that required for an orthophosphate is a common characteristic of the group. Another prominent feature consists in the peculiar and diverse modes in which the water present in the hydrated species is held. For several reasons the moderate-sized group of the hydrated aluminium phosphates has been selected for renewed investigation. Light has been thrown upon the relations of these compounds by accurate analyses, in which a special and uniform method of desiccation has been adopted; in which silver vessels have been substituted, where deemed preferable, for those of glass and porcelain; and in which sodium hydrate, from metallic sodium, has been used, instead of alcoholic potash, for retaining alumina in solution. The present communication contains an account of a considerable number of analyses conducted with the precautions named above; but it does not pretend to offer an exhaustive treatment of the subject, nor a decisive opinion upon all the questions of chemical constitution involved in the inquiry.

§ II. As a preliminary step towards the discovery of the constitution of the hydrated aluminium phosphates, it was deemed expedient to ascertain with what tenacity the normal native aluminium hydrate and the normal native aluminium phosphate respectively retained their water. This mode of experimenting was expected to disclose how far that common assumption could be correct which attributed to the native basic aluminium phosphates such a formula as—

$$x\mathrm{Al_2P_2O_8},\ y\mathrm{Al_2H_6O_6},\ z\ \mathrm{aq.}$$

Fortunately a suitable native hydrate and native phosphate are known; the former being the gibbsite of Dana, now often called hydrargillite; the latter being the variscite of Breithaupt.

§ III. *Gibbsite.*—On submitting gibbsite to the process of desiccation, the mineral retained the whole of its moisture, not only in dry air and in vacuo, but also at 100° C. in the air-oven. The analytical details are here given:—

Anal. 1. Gibbsite, from Richmond, Massachusetts—

·309 gram lost ·003 gram H_2O in vacuo = 0·97%
·309 ,, ,, ·001 at 100° C. = 0·30%
·309 ,, ,, nothing in water-oven
·309 ,, ,, ·106 on ignition = 34·30%.

Anal. 2. Gibbsite, from Villa Rica, Brazil—

·213 gram lost ·002 gram H_2O in vacuo = 0·93%
·213 ,, ,, nothing up to 100 C.
·213 ,, ,, ·069 gram on ignition 32·39%.

Both the specimens were of great purity, neither containing any silica, and a mere trace of phosphate being present in No. 2 only; this latter specimen was uniformly crystalline. The mean percentage of combined water, corrected for accidental moisture, amounted to 33·73—a figure closely agreeing with the number demanded by theory, namely, 34·48. This percentage of water is that required by the formula Al_2O_3, $3H_2O = Al_2H_6O_6$, the normal aluminium hydrate.

§ IV. *Variscite.*—We have now to consider the mode in which the water present in such of the native aluminium phosphates as are free from excess of base is held. For the solution of this problem it might have been thought that several native species would have served. But there proved to be but one mineral of sufficiently definite character, obtainable for this purpose in adequate quantity: this was *variscite*, a phosphate found at Messbach, Saxon Voigtland, and described by Breithaupt in 1837. It is clearly identical with the callainite of Damour, a mineral the *provenance* of which is unknown, but of which some polished beads and ornaments were found in a Celtic grave at Morbihan. The two other normal aluminium phosphates which have been described are the gibbsite of Hermann, and zepharovichite. Of the latter, I have been unable to obtain an authentic or adequate supply: of the former mineral nothing definite is known; its separate existence is perhaps doubtful. Thus my work has been perforce limited to variscite.

On submitting a carefully selected and prepared specimen of variscite to the desiccating processes before mentioned, it was evident that the water in this mineral was held far more loosely than that in calaite, or true turquoise, and in wavellite. The analytical results are here given:—

Variscite[1] (spec. grav. 2·24), from Messbach.

Anal. 3. ·119 gram gave ·084 gram $Mg_2P_2O_7$ = 45·15% P_2O_5
,, ,, ,, ·0388 ,, Al_2O_3 = 32·60% Al_2O_3
Anal. 4. ·371 ,, lost ·01 ,, H_2O in vacuo = 2·64%
,, ,, ,, ·08 ,, H_2O at 100° = 21·11
,, ,, ,, ·004 ,, H_2O on ignition = 1·08
Anal. 5. ·32 ,, ,, ·0795 ,, H_2O on ignition = 24·84
,, ,, gave ·005 ,, Fe_2O_3 = 1·56.

[1] Containing some Fe_2O_3; *vide* analysis 5.

An inspection of these figures shows that variscite loses nearly all its water at 100°C., but practically none, or at least not a whole molecule, in vacuo over sulphuric acid. If we reject, as non-essential, the 2·64% H_2O lost in vacuo, then the percentages deduced from the analyses given above will stand thus :—

	Experiment.	Theory. Al_2O_3, P_2O_5, 4 aq.
Alumina, ...	31·04	32·45
Ferric Oxide, ...	1·56	—
Phosphorus Pentoxide, . .	45·15	44·82
Water, ...	23·27	22·73

§ V. According then to the above-given analyses of normal native hydrate and phosphate of aluminium, the former loses no water at 100°, the latter all. The results of R. Helmhacker's experiments with the supposed variscite of Freienstein, near Leoben,[2] are not in accordance with this view so far as regards the normal phosphate. He obtained 16·11% water lost at 100°, and 17·57% on ignition. The alumina amounted to 34·46%, while the phosphorus pentoxide was only 25·69. These figures are allowed by Helmhacker to point to an admixture of diaspore with his variscite in the ratio of 4 : 5; now, as diaspore resembles gibbsite in its total retention of water at 100°C., we possess, in these apparently anomalous results, an actual confirmation of the conclusion to which my own experiments had led. Possibly Helmhacker's 100°C. may have been the conventional expression for the temperature of the water-oven, which would fall considerably short of that figure. With an air-oven at 100° C. his mineral would probably have lost more than 16·11%.

§ VI. Here perhaps it may be well to introduce the analysis of a mineral from Langen Striegis which, though in physical characters resembling the peganite of Breithaupt, yet gave very different results from those obtained with that mineral (or what we must assume to have been that mineral) in the hands of Hermann. He obtained numbers corresponding to those of a member of the calaite group ($2Al_2O_3$, P_2O_5, $6H_2O$); but I find that my specimen is chemically and physically much nearer variscite than calaite. Anyhow, the assumption that this mineral is nothing but wavellite cannot be maintained. If not a perfectly definite species, yet its behaviour when heated to 100° marks it out from wavellite and from nearly all the other phos-

[2] Tchermak's *Min. & Petr. Mitth.* ii., p. 229, *et seq.*

phates of aluminium. While in vacuo it loses nothing, at 100° C. (in the air-oven), all the water in the mineral is disengaged. In the water-oven the change is incomplete, for at 94°, the maximum temperature reached by my water-oven, rather less than half the total water was removed. It may be noted that the curious pink tint which peganite assumes when heated in a bulb-tube was acquired in the air-oven at 100°, but not in the water-oven at a temperature only a few degrees lower.

My analysis of a sample of this so-called peganite from Striegis, gave the following results :—

Anal. 6. ·374 gram lost nothing in vacuo, but lost
·035 ,, H_2O in water-oven, and
·047 ,, H_2O in air bath at 100°, and gave
·005 ,, SiO_2
·133 ,, Al_2O_3 and
·243 ,, $Mg_2P_2O_7$.

Translated into percentages and compared with the numbers demanded by the nearest formula, these results are here shown :—

	Experiment.	Theory. $7Al_2O_3, 6P_2O_5, 24H_2O$.
Alumina, ...	35·30	35·91
Phosphorus Pentoxide . .	41·56	42·53
Water, ...	21·92	21·56
Silica, ...	1·33	—
	100·11	100·00

When the correction for intruding silica is made, the correspondence between experiment and theory becomes quite satisfactory. Still it would scarcely be justifiable to accord specific rank to this mineral on the strength of a single set of numbers, and I should prefer to regard the specimen analyzed as variscite slightly admixed with a more basic aluminium phosphate.

§ VII. It is, on the whole, evident, from the analyses of gibbsite, variscite, and peganite, which I have now given and discussed, that any native basic hydrate of aluminium, if it were made up, say, of one molecule of the normal native hydrate simply associated with one molecule of the normal native phosphate, might be expected to lose, when heated to 100°, *all* the water attached to the latter compound, and *none* of that belonging to the former.

§ VIII. *Calaite.*—Now we have in calaite a mineral adapted for the trial of this question. There can be no doubt that the essential part of pure turquoise or calaite may be represented by the empirical formula—

$$2Al_2O_3,\ P_2O_5,\ 5H_2O.$$

But we have to ask whether the constitution of this species may not be expressed by some more precise arrangement, such as

$$Al_2O_3,\ P_2O_5,\ 2H_2O + Al_2O_3,\ 3H_2O,$$

namely, one molecule of a hydrated normal aluminium phosphate with one molecule of the normal aluminium hydrate? Now we have seen that the latter compound as occurring in nature loses no water at 100°, while the nearest approach to the former compound (namely variscite) loses all its water at this temperature. Calaite, then, if containing such a phosphate, should part with $\frac{2}{5}$lbs. of its water below 100° C. As it retains all, even when heated beyond this point, it will be more in accordance with the results of experiment if we express the molecule of calaite somewhat after the following fashion:—

$$\begin{matrix} 2Al_2O_3 \\ H_2O \end{matrix}\ \begin{cases} P_2O_5 \\ 4H_2O, \end{cases} \quad \text{or} \quad \begin{matrix} Al_4 \\ H_2 \end{matrix}\ \begin{cases} 2PO_4 \\ 8HO, \end{cases}$$

which may be abbreviated into

$$\begin{matrix} Al_2 \\ H \end{matrix}\ \begin{cases} PO_4 \\ (HO)_4 \end{cases} \text{ or } Al_2HPO_4(HO)_4.$$

The analyses upon which this view is founded are three, one published in 1864,[3] and the others lately made for the purposes of this report.[4] The relation of the cupric, ferrous and manganous phosphates to the main constituent of calaite having been fully discussed elsewhere, a few only of the later analytical results need be cited here. In the case of a very pale and pure specimen of calaite from Nishapur, Persia, the following figures were obtained:—

·584 gram lost ·018 gram H_2O in vacuo over H_2SO_4 = 3·08%
·584 „ „ ·118 „ „ on ignition = 20·85%.

Nothing was lost at 100° in the air-oven: but of the 20·85% water driven off on ignition the last 4% was retained with greater tenacity. Similar results were yielded by a Thibetan turquoise.

§ IX. Two other aluminium phosphates have been described, apparently belonging to the calaite or turquoise group, and differing from calaite in the proportion of water only. One of these is the peganite analyzed by Hermann, a Striegis mineral; the other is fischerite from Nischne Tagil, also analyzed by Hermann. I find that three distinct minerals from Striegis go under the name of peganite. One of these is

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[3] *Chemical News*, x. p. 290.
[4] Zellner's analysis of a Silesian calaite confirms this view.

nothing but wavellite; another is very nearly related to variscite, if it be not identical with it.[5] The peganite of Arkansas, according to A. H. Chester,[6] is also identical with variscite. But there is a third mineral known as peganite found also at Striegis in Saxony; this is very near wavellite, but contains less water. What is probably the same mineral from Nobrya[7] in Portugal has been analyzed by Lichtenberger and Frenzel. As to fischerite, I have not been able to secure an authentic specimen sufficiently ample for analysis.

§ X. The next group of native aluminium phosphates may now be discussed. Its best known member is wavellite, to which the formula

$$2Al_2P_2O_8,\ Al_2H_6O_6,\ 9\ aq$$

is usually assigned. But in spite of the very numerous analyses of wavellites from different localities which have been made, the formula for this species cannot be said to have been ascertained. Two circumstances make it doubtful. Like many other fibrous minerals, wavellite always retains, under ordinary atmospheric conditions of barometric pressure, moisture, and temperature, about two per cent. of moisture removable in vacuo, or in dry air, or by a slight increase of temperature; so the question arises "Is this water essential or accidental?" Doubtless many hydrated minerals, when removed from the natural conditions under which they were formed, lose essential or constitutional water very readily, but in such cases the percentage of loss is generally much larger than two. The second circumstance which interferes with the exact determination of the combined water in wavellite is the presence of fluorine in this mineral. This element, which probably occurs to the extent of two per cent., must be regarded as an acid element, replacing either the phosphoric constituent or oxygen. If so, it will lower the proportion of phosphorus pentoxide found, and raise that of the water as determined by loss. I have considered this question in a previous research,[8] and shown that a formula with $11H_2O$ has much to recommend it. It may be added that vacuum-dried wavellite loses no water at 100° C., but 22% at 200° C., and 4% at a low red heat. And if those published analyses of wavellite in which the fluorine has been determined be studied, it will be seen that the water is lower than that commonly assigned to this mineral. But, after all, it is not improbable that we group under wavellite several minerals differing from each other by 1 aq. Possibly there are four such members of the wavellite group:—

1. *Planerite*, ... $3Al_2O_3,\ 2P_2O_5,\ 9\,aq.$
2. *Coeruleolactite*, . . $3Al_2O_3,\ 2P_2O_5,\ 10\,aq.$
3. *Wavellite*, ... $3Al_2O_3,\ 2P_2O_5,\ 11\,aq.$
4. *Striegisane*, . . . $3Al_2O_3,\ 2P_2O_5,\ 12\,aq.$

Of Coeruleolactite I shall have something to say further on, but it

[5] See § VI of this Report.
[6] Jahr. Min.. 1872, 819.
[7] An analysis is given in § XII.
[8] *Jour. Chem. Soc.*, Feb., 1873.

may be useful to give here some additional evidence as to the existence of the fourth member of this group. Its formula is that commonly given to wavellite, but may perhaps more properly belong to the Striegisane of Breithaupt.

§ XI. *Striegisane.*—It was very difficult to select for analysis sufficient of this mineral without including some small specks of the slaty gangue. But as the weak acid used to dissolve the phosphate may be assumed to have been practically without solvent action on the gangue, the errors due to traces of the latter may be eliminated by recalculating the percentages after deducting the insoluble silicious residue. The results of my analysis are here given:—

Anal. 7.		·443	gram striegisane in vacuo over H_2SO_4	
	lost	·0082	,, H_2O	= 81·5%
	,,	·1188	,, H_2O on ignition	= 26·81%
	gave	·018	,, insoluable matter	= 4·06%.
Anal. 8.		·2215	,, striegisane	
	gave	·075	,, Al_2O_3	= 33·86%
	,,	·002	,, Fe_2O_3	= ·90%
	,,	·114	,, $Mg_2P_2O_7$	= 32·90% P_2O_5.

These percentages, after deduction of gangue, become—

H_2O	lost in vacuo		1·92%
H_2O	,, on ignition		27·94%
Fe_2O_3	,,	,,	·93%
Al_2O_3	,,	,,	35·29%
P_2O_5	,,	,,	34·31%
			100·39.%

The above 27·94% water lost on ignition really includes some fluorine; how much, the scarcity of the mineral prevented me from determining. If it did not exceed two per cent., then this specimen of striegisane, though clearly related to wavellite, may perhaps serve to strengthen the view that two minerals, differing merely by 1 aq., have hitherto been included under that species. The 2% water lost in vacuo and the absence of any further change at 100° are characters of wavellite to which species Erdmann[9] long since releglated Breithaupt's striegisane. Possibly the kalk-wavellite of Kosmann[10] may belong here. At all events I find in it a mere trace of lime, and a rather high percentage of water retained at 100°.

§ XII. *Peganite, &c.*—Amongst the numerous minerals or mineral varieties which have been "split" into species by some mineralogists, and by others "lumped" under wavellite, there is one which has been found at Nobrya in Portugal, and which very closely resembles some specimens of peganite. In looking over my Striegis phosphates I noticed a specimen which seemed to belong here. The amount

[9] Schw. J. lxix., 154.

[10] L. G. Ges. xxi., 795 (1869).

available for analysis was not large, but the following results were obtained with a quantity of material sufficient for an accurate analysis: it should be said that ·011 gram silica has been deducted from the amount taken for analysis:—

Anal. 9. ·4085 gram in vacuo over sulphuric acid

lost	·0125	,, H_2O	= 3·06%
,,	·0545	,, H_2O in water-oven	= 13·34%
,,	·035°	,, H_2O on ignition	= 8·56%
gave	·164	,, Al_2O_3	= 40·12%
,,	·225	,, $Mg_2P_2O_7$	= 35·23% P_2O_5.

Now these results at the first glance might be taken to suggest a wavellite formula, such as $3Al_2O_3$, $2P_2O_5$, 11 aq., which requires almost precisely the percentage of water here given, and nearly the percentages of Al_2O_3 and P_2O_5. But the very large loss of water suffered by this Striegis mineral in the water-oven separates it from the species wavellite at once. And if we consider the difficulty of avoiding an excess of Al_2O_3 in an analysis, and the liability to count as water the hydrofluoric acid which escapes on strongly heating a phosphate of this group, I think it may be concluded that the experimental percentages of alumina and water are both above the truth, while the phosphorus pentoxide should be supplemented, in critically weighing the analytical results, by a small addition corresponding to the lost fluorine. From these considerations it is clear that the specimen now under discussion differs decidedly from wavellite in its slight hold of most of the water present, however near it may be in its percentage composition. But there is reason to think that the mineral under discussion, as well as wavellite itself, retains at ordinary temperatures 2 or 3% of interstitial or mechanical moisture, which in both cases is easily removed in vacuo over sulphuric acid. Recalculating the analytical results on this assumption, but without making any of the other suggested corrections, we reach the following percentages:—

	Experiment.	Theory.
Alumina, ...	41·41	39·83
Phosphorus Pentoxide, . .	36·34	36·79
Water, ...	22·60	23·32
	100·35	100·00

The theoretical numbers here given are those required by the formula $3Al_2O_3$, $2P_2O_5$, 10 aq. If the excess in the analytical per-

centages were simply thrown on the alumina, the discrepancy between experiment and theory would not be unreasonably large, particularly as the alumina did contain traces of ferric oxide. The present analysis is alluded to in my classification table (§ XV.) under the signature "Coeruleolactite," for the published analyses of that mineral (by Petersen and by Genth) from two localities, Rindsberg, Nassau, and Chester Co., Pennsylvania, carefully studied, lead to the formula $3Al_2O_3$, $2P_2O_5$, 10 aq. above given. I do not, however, find that any experiments have been made, by the analysts just named, to determine the tenacity with which the water in coeruleolactite is held.

§ XIII. *Coeruleolactite.*—It seemed important to secure some information on this point in order to learn what warrant there might be for including these four minerals found respectively at Striegis, at Nobrya, at Rindsberg, and in Chester Co. Pa., under the same specific name. With this object in view, I made the following trials with a picked specimen of coeruleolactite from the last-named locality: the percentages have been recalculated after the deduction of the undissolved silica :—

Anal. 10.	·1235 gram lost in vacuo	·004 gram	H_2O =	3·24%
	·1235 ,, ,, in water-oven	·003 ,,	H_2O =	2·43%
	·1235 ,, ,, at 100°	·007 ,,	H_2O =	5·67%
	·1235 ,, ,, on ignition	·018 ,,	H_2O =	14.57%.

It is worth while recalculating these results once more after deducting the small percentage of water lost in vacuo. Then we find that the vacuum-dried mineral lost 8·37% H_2O at 100°C. in the air-oven; and 15·06% more on ignition. This result confirms my conclusions as to the position of the Striegis mineral referred to in § XII., and tends to show that the group of minerals under discussion may be referable to a single species, differing from wavellite not merely in a lower percentage of water but also in constitution. It is true that the analytical results, so far as the percentages of water lost at different temperatures are concerned, are not alike in the two minerals analyzed, but in both cases we have a notable proportion of water lost and a notable proportion retained at 100°. This suffices to suggest for these minerals a constitution in which both the normal hydrate and the normal phosphate bear parts, being associated in such a way as to retain in a measure their ordinary relations to their own combined water.

§ XIV. *Evansite.*—This species, from Zsetczik in Hungary, is at once the most basic and the most highly hydrated of all the native aluminium phosphates. It occurs in colourless and nearly transparent nodular concretions, and was formerely mistaken for allophane. The late David Forbes analyzed[11] it with such care that nothing remained to be accomplished, save to ascertain the condition in which the water exists

[11] *Philosophical Magazine*, November, 1864.

in the mineral. No doubt can be entertained of the title of evansite to specific rank, although its claim has not been duly recognized in mineralogical text-books.[12] I give here the mean percentages obtained by Forbes from his three analyses, and the corresponding numbers demanded by the formula he adopted:—

	Experiment.	Theory, $3Al_2O_3, P_2O_5, 18H_2O$.
Alumina, ...	39·31	39·78
Phosphorus Pentoxide, . .	19·05	18·35
Water, ...	39·95	41·87
Silica, ...	1·41	—
Loss, ...	·28	—
	100·00	100·00

On placing the finely-powdered mineral over sulphuric acid in vacuo it lost little more than traces of moisture: but at 100°, or rather in the water-oven, a very different result ensued. Here are the figures:—

Anal. 11. ·37 gram evansite lost in vacuo in 36 hours
·004 ,, H_2O. At 100° it sustained a further loss of
·0795 ,, H_2O. On moderate ignition the remainder,
·0685 ,, H_2O, was evolved.

The percentages of water to which the above results correspond are as follow:—

Loosely combined water, lost at 100°	22·56%
Water, lost on ignition, ...	18·51%
Total water, ...	41·07%

Now if evansite contains $18H_2O$, the loss of

10 H_2O	corresponds to	23·26%
8 H_2O	,, ,,	18·61%
		41·87%

These numbers leave no doubt as to the peculiar position occupied by evansite amongst the aluminium phosphates. In accordance with the

[12] Rammelsberg's *Mineral-Chemie*, 2nd ed., vol. ii., p. 320.

system deduced from the study of other members of this series, we may arrange its formula thus—

$$3Al_2O_3,\ P_2O_5,\ 8H_2O + 10\ aq.$$

Here the 10 aq. represent those molecules of water which are disengaged in the water-oven. How the $8\,H_2O$ are combined with the Al_2O_3 and the P_2O_5 has not been ascertained, but this may be said, that the fixity of this water at or near 100° forbids the assumption that in evansite we have an association of $Al_2P_2O_8 2$ aq. with $2\,Al_2H_6O_6$.

If there be no doubt that the entire molecule of evansite contains not less than 18 of H_2O, the relation of liskeardite[13] to this species will have to be reconsidered. If that mineral be "an arsenical evansite" it should contain 2 molecules of water more than have been assigned to it. Its formula has been expressed hitherto thus—

$$3\,R_2O_3,\ As_2O_5 + 16\,H_2O,$$

where R_2O_3 represents alumina with some ferric oxide.

§ XV. The following Table will prove useful in comparing the experimental numbers given in this Report with those required by theory.

PROPOSED CLASSIFICATION OF ALUMINIUM PHOSPHATES.

SPECIES.	FORMULA.	Theoretical Percentages of		
		Al_2O_3 (102·6).	P_2O_5 (142).	H_2O (18)
	GROUP I.			
?	$Al_2O_3,\ P_2O_5,\ 2$ aq.	36·56	50·61	12·83
VARISCITE, . . .	$Al_2O_3,\ P_2O_5,\ 4$ aq.	32·40	44·85	22·74
ZEPHAROVICHITE, .	$Al_2O_3,\ P_2O_5,\ 6$ aq.	29·09	40·27	30·63
?	$Al_2O_3,\ P_2O_5,\ 8$ aq.	26·40	36·54	37·05
	GROUP II.			
COERULEOLACTITE, .	$3Al_2O_3, 2P_2O_5, 10$ aq.	39·83	36·79	23·32
?WAVELLITE, . . .	$3Al_2O_3, 2P_2O_5, 11$ aq.	38·97	35·95	25·07
?STRIEGISANE, . .	$3Al_2O_3, 2P_2O_5, 12$ aq.	38·10	35·16	26·74

[13] N. S. Maskelyne, *Nature*, August 16th, 1878.

CLASSIFICATION OF ALUMINIUM PHOSPHATES—*continued.*

SPECIES.	FORMULA.	Theoretical Percentages of		
		Al_2O_3 (102·6).	P_2O_5 (142).	H_2O (18).
	GROUP III.			
CALAITE, . . .	$2Al_2O_3, P_2O_5, 5$ aq.	46·93	32·48	20·57
PEGANITE, . . .	$2Al_2O_3, P_2O_5, 6$ aq.	45·08	31·19	23·72
?	$2Al_2O_3, P_2O_5, 7$ aq.	43·36	30·01	26·63
FISCHERITE, . . .	$2Al_2O_3, P_2O_5, 8$ aq.	41·77	28·91	29·31
	GROUP IV.			
EVANSITE, . . .	$3Al_2O_3, P_2O_5, 18$ aq.	39·78	18·35	41·87

§ XVI. In concluding this Report, it is my agreeable duty to thank the Royal Irish Academy for the liberal grant which enabled me to secure the material upon which I have worked. And I cannot refrain from naming in this place the generous gift made to me by Mr. Henry Willett, F.G.S., of Brighton. He learnt that a large and efficient air-pump was necessary for the proper carrying out of the drying in vacuo of the several mineral species analyzed during this inquiry. Mr. Willett gave me for this purpose one of Bianchi's magnificent air-pumps, at a cost of something like fifty pounds.

LXXVII.—On a New and Expeditious Method for the Determination of the Nitrites, under different Circumstances. By Edmund W. Davy, A.M., M.D., M.R.I.A., Professor of Forensic Medicine, Royal College of Surgeons, Ireland, &c.

[Read, April 24, 1882.]

As the existence of Nitrites and Nitrates in different natural waters has been regarded (under certain circumstances) as affording evidence of previous sewage contamination, the determination of the presence or absence of such compounds, and their quantitative estimation when present, in the waters employed for domestic purposes, may be a mattter of much importance in a hygienic point of view; and though we have some delicate tests for the detection in such of the presence both of nitrites and nitrates, as well as different methods for their conjoint quantitative determination, there is no very simple or expeditious method for the separate estimation of nitrites in waters, which may sometimes be required, if we except that not long since proposed by P. Griess, which method I shall presently describe, and compare with the one I have myself devised, and which I shall now lay before the Academy.

In making lately some experiments on certain nitrites, I observed a reaction, which, as far as I am aware, has not hitherto been described; and this being one of extreme delicacy, I have founded on it a new method not only for the detection of the presence, but likewise for the quantitative determination of the nitrites under different circumstances, but especially in the case of natural waters, for which it is peculiarly suitable. The reaction referred to is that of nitrous acid, or of a soluble nitrite, on the well-known substance, gallic acid; thus when an aqueous solution of that latter acid is brought in contact with a soluble nitrite, the mixture, unless the amount of the latter present be very small, will soon acquire a yellow or yellowish-brown tint, which will increase in depth up to a certain point, after which the colour remains permanent, whilst, at the same time, minute globules of gas make their appearance in the mixture. If, however, the quantity of nitrate present be exceedingly small, it will require several hours, or even some days, to complete the reaction at the ordinary temperature. By the application, however, of heat,[1] and bringing the mixture to the boiling point, even in the case of the most dilute solutions, the reaction will be completed in a few moments. This development of colour under the circumstances stated is evidently due to the oxidation of the gallic acid, at the expense of the nitrous acid,

[1] The continued application of heat has the effect of slightly diminishing the depth of colour developed in this reaction.

whereby the compound known under the name of tanno-melanic acid seems to be formed, whilst nitric oxide and carbonic acid gases are evolved. The following equation represents the changes which occur in the reaction:—

Gallic Acid.		Nitrous Acid.		Tanno-Melanic Acid.		Carbonic Acid.		Nitric Oxide.		Water.
$C_7H_6O_5$	+	$2HNO_2$	=	$C_6H_4O_3$	+	CO_2	+	$2NO$	+	$2H_2O$.

These changes, with the development of colour, take place in neutral as well as in acid solutions, but more readily in the latter, and when they are heated, than at the ordinary temperature, as already observed. The colouring principle which is so produced seems to be the same substance that is formed by the gradual oxidation of gallic acid in aqueous solution by exposure to the air; or when this takes place more rapidly, by the solution being rendered alkaline by the addition of one of the alkalies before exposing it to its influence. The colouring matter so formed is unaffected by diluted acids—at least diluted sulphuric, nitric, and hydrochloric acids had no apparent effect on it; and the organic acids, acetic, oxalic, and tartaric, even in a concentrated condition, did not seem to produce any change. It is also very permanent, and does not appear to be affected by exposure to air and light, even after being a long time subjected to their influence.

The depth or intensity of the colour produced being in direct proportion to the amount of nitrite reacting on the gallic acid, a ready means is afforded for the quantitative determination of the nitrites. Thus, if a standard solution be prepared, containing a known quantity of nitrite, and if a given amount of water or solution under examination yielded with gallic acid a certain shade or depth of colour, and if the same bulk of the standard solution, or of a mixture of it with distilled water in known proportion, developed the same tint, the former would be considered to contain the same amount of nitrite as the latter, and by thus comparing the tints produced by the waters under examination with those caused by solutions containing known quantities of nitrite, the quantitative estimation of such may be quickly accomplished, just as in Nessler's process (now so much employed by chemists) the determination of ammonia is so readily effected. Indeed the colour which is developed by the action of the nitrites on gallic acid most closely resembles that produced by ammonia on Nessler's reagent. The process, too, is conducted pretty much in the same way, except that we have a standard solution of an alkaline nitrite, instead of one of ammonia; and the test reagent is one containing gallic acid, instead of Nessler's solution; and finally, that the water or mixture, after the addition of the gallic acid solution, and a few drops of either sulphuric or hydrochloric acid, is heated to boiling in a test tube and allowed to cool; after which it is placed in a cylindrical flat-bottomed glass, to compare more accurately the degree of colour produced by the water under examination with that containing some known quantity of nitrite.

The gallic acid solution which I have employed for the determination of nitrites is a strong or saturated aqueous one, which, if not colourless, can be easily made so by boiling it for a few minutes with animal charcoal, filtering the mixture whilst still warm, and then adding immediately to the filtrate sufficient sulphuric or hydrochloric acid to render it strongly acid, which addition I have found prevents, to a great extent, the tendency of aqueous solutions of gallic acid to become of a yellow or brownish tint on keeping, which well-known property is due, as already observed, to the tendency of that acid to oxidize under such circumstances; but by the addition of the acids stated, I have kept solutions of gallic acid, which were even exposed to the air in open vessels, for over two months without undergoing any change in colour.

As to the standard alkaline nitrite solution, it may be readily prepared by decomposing a hot aqueous solution of silver nitrite with potassium or sodium chloride, and after the subsidence of the silver chloride formed, diluting the solution to the required amount. The one I employed was made, as Dr. Frankland directs, in his "Water Analysis," for the preparation of the standard alkaline nitrite solution to be employed in Griess's method for the determination of nitrites, which is prepared as follows:—0.406 gram of pure silver nitrite is dissolved in boiling distilled water, and pure potassium or sodium chloride added, till no more silver chloride is precipitated. The solution is made up to one litre, and the silver chloride being allowed to settle, 100 c.c. of the clear solution is made up to one litre, of which 1 c.c. is equivalent, as he says, to 0.01 m.gram of nitrous anhydride (N_2O_3); and he further adds, that this solution should be kept in closely-stopped bottles, quite full. A solution at least double this strength will, however, be found more convenient for my test. I may also observe that I have likewise used a standard solution made by taking the commercial potassium nitrite and boiling it along with alcohol, which will dissolve out the potassium nitrite, leaving undissolved the nitrate and other impurities; and this alcoholic solution, on evaporation and drying the residue, will furnish the nitrite suitable for this purpose.

In using this test a convenient quantity of water to employ is 25 c.c., which can be easily heated in a test tube of somewhat larger capacity, along with 1 or 2 c.c. of the gallic solution, and a few drops of sulphuric or hydrochloric acid, and, when the mixture has cooled, transferring it to a flat-bottomed cylindrical glass, where the depth of colour can be more readily determined, and compared with that yielded by equal bulks of different mixtures of the standard solution with distilled water. But where the amount of nitrite is very minute, it will perhaps be better to use at least 50 c.c. of the water under examination. I should observe that the nitrates do not produce the reaction described with gallic acid, and, unless they are present in large quantity, do not affect the test; and that it (the reaction with the nitrites) appears to be uninfluenced by the presence of the different saline and

earthy salts that occur in natural waters, as well as by the organic matters that may be there occasionally. It might be naturally supposed that soluble salts of iron (which are sometimes present to some extent in certain waters), producing as they do the well-known black or ink-like reaction with gallic acid, would preclude its employment as a means of estimating nitrites, where the former salts were present; but this is not the case; for the iron may be separated by the addition of ammonia and filtration, after which I have found that the filtrate, having been acidified, may be treated with gallic acid, for the estimation of nitrites. It appears, therefore, that none of the substances which would be likely to occur in natural waters interfere with the employment of this test.

As to what may be the exact limits of its indications, I have not yet been able to determine; but I have readily detected, by its use, an amount of nitrite in water equivalent to one part of nitrous acid in about twenty millions parts of water.

I have made a number of comparative experiments with this test of mine and those hitherto proposed for nitrites, but chiefly with that of P. Griess, already referred to, as Dr. Frankland (who is one of the first chemists of the day) has stated in his "Water Analysis," that it is the only trustworthy means we have for the estimation of nitrites.

This test, I may briefly say, depends on the reaction of nitrous acid on metaphenylene diamine, or meta-diamido-benzol, a derivative of benzol, whereby an orange-coloured compound is produced, by the oxidation of this complex basic substance. This reaction is one of extreme delicacy, and the test is carried out pretty much in the same manner as the well-known Nessler's method for the determination of ammonia; or of mine, just described, for that of nitrites; the depth of colour produced by the test solution, with the water under examination, being compared with that of one containing a known quantity of nitrite; the details, however, of the method will be found fully stated in Dr. Frankland's "Water Analysis."

From several comparative experiments I have made with Griess's method and that of my own, I have come to the conclusion that the latter is almost, if not quite, as delicate a test for the nitrites as the former. I have, however, observed this difference between them, that when the proportion of nitrites present was considerable, that then Griess's test gave a more decided reaction, or that the colour produced was of greater intensity than in the case of the gallic acid test; but that when the amount of nitrite was exceedingly minute, that then there was but little or no difference in the delicacy of their indications. In some other respects, however, the test which I have proposed possesses advantages over that of Griess; thus the metaphenylene diamine is at present a compound very difficult to be procured; so much so that though I applied twice, lately, to one of the best known firms in London for the manufacture of chemicals (Messrs. Hopkin & Williams), they were unable to procure me a little of that substance; and that which I operated on was kindly given to me by my friend

Dr. Tichborne, who procured it direct from Berlin. On the other hand, the reagent used in my test may be got for a few pence at any druggist's shop: again, Griess's test solution will not keep, as it quickly acquires the same colouration that is produced by the reaction of nitrous acid or a nitrite on it, even when it is kept in closely-stoppered bottles; and therefore requires to be freshly made and titrated almost every time it is employed; whereas the gallic acid solution which I have recommended will, I find, keep for a very considerable time without apparently undergoing any alteration requiring its fresh titration, which is an important advantage. In conclusion, I may add, that whatever may be the comparative merits of the two tests contrasted, I have but little doubt that the one I have proposed will be found to be a useful and expeditious method for both the qualitative and quantitative determination of the nitrites under different circumstances.

LXXVIII.—On the Jointing of Rocks in Relation to Engineering, especially the Tunnelling of the Strait of Dover. By Professor William King, D. Sc.

[Read, 24th April, 1882.]

For some years past having been at different times engaged in studying the jointed structure of rocks,[1] I may lay some claim to taking a part in the discussion of a question in Engineering which public enterprise has lately elevated to a subject of international importance.

But before proceeding further, I may be allowed to make a few remarks on some points introductory to the subject in hand.

Already, it may be assumed, the promoters of the proposed Channel Tunnel have had their attention called to the probability that the rocks to be penetrated are so greatly affected by dislocations (faults), and fractures of the ordinary kind (that is, resulting from disruption), also to some of them possessing an openly porous character, as to prove serious detriments to the undertaking; at the same time it must be admitted that some other points of vital importance in submarine engineering of the kind appear to have been but slightly attended to, or altogether overlooked.

It is well known that the chalk and immediately associated earlier rocks, in Kent and Sussex, have been flexured into the great elliptical dome, known as the anticlinal of the weald—its longitudinal axis running generally near an east and west course. The consequence is, that the bedding of these rocks variously intersects the horizon from a low angle to a high one. Not unfrequently the partings, which define the bedding, are penetrable by water. Now, anyone who has observed the chalk, with the adjoining tertiary sands, clays, and pebble beds, in the Isle of Wight, standing in a nearly vertical position, must admit that, if such partings were at the bottom of the adjacent sea, the water would necessarily flow into them. It may be doubted that the beds of chalk or other rocks in the Channel are standing at a high angle; though in some places in the North Downs, notably St. Margaret's, Chapel Hill, they have quite a sudden dip, as mentioned by Hopkins; but there are no positive grounds for altogether excluding from the line of the tunnel beds lying at angles not exempt from danger: even if their dips be as low as 15°, which is a common figure, bedding partings, it is to be apprehended, would serve as channels for the water to penetrate to the roof, or sides of any submarine excavation.

Moreover, geologists who have examined the counties under consideration have noticed the frequent occurrence in the chalk of "sand pipes" or "gravel pipes"—large cylindrical openings in a vertical

[1] *Transactions* of the Royal Irish Academy, vol. xxv., pp. 605–662 (1875); An Old Chapter of the Geological Record (Appendix), pp. 107–119 (1881).

position, and from 40 to 80 feet deep, which, from the arrangement of their contents, have evidently been swallow holes, down which water passed into subjacent catch basins.

That similar openings are now in existence in the Channel may be considered as more than probable, seeing that "sand pipes" in Kent, as brought to light by Professor Prestwich, though at present at a considerable elevation above the sea level, must have been at the bottom of the sea during some portion of the Pliocene period, since occasionally they contain the casts and other remains of marine shells (*Terebratula grandis* and *Lutraria elliptica*) living at the time.[2]

But dislocations, fractures of disruption, inclined bedding partings, porosity and sand pipes, are not the only sources of water leakage that may be met with while excavating the Channel Tunnel: another, if a not more serious one, remains to be noticed. Rock jointing possesses characters favouring the idea of its being totally distinct from fractures of disruption—rather, a divisional structure developed by no ordinary mechanical agency; but whether this be the case or not, jointing requires to be closely considered by all parties immediately interested in carrying out the proposed undertaking to a successful issue.

The phenomenon now entered upon consists of regular and persistently parallel fissures, characteristic of both stratified and unstratified rocks: the softest shales and hardest granites are alike affected by it; and these may be of any geological age—from the Archæans up to the Eocenes. Altogether independent of bedding or stratification, the planes of jointing intersect those due to deposition, inasmuch as their usual position is oblique, or rectangular, to bedding, whether it be horizontal or inclined. Although, in general, from under an inch and often many more apart (produced by the erosive action of the water and other wasting agencies, also by stratic disturbances, making a joint resemble an ordinary disruptive fracture), the conjunctive planes or walls of a joint, in their normal or original condition, are in the closest possible contact, appearing as if they had been made by the thinnest and sharpest cutting instrument; and this is equally the case with foreign bodies, as blocks or pebbles of granite enclosed in conglomerates: the same planes have not uncommonly a surface as smooth, and occasionally as lustrous (like those of mineral cleavage), as if they had come direct from the hands of a marble polisher. The joints lie at varying distances from one another, having usually one, two, or more feet of separation; but examples are rather frequent in which they lie from an eighth to above an inch apart.

In the case of rocks lying horizontally, jointing, besides affecting a

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[2] *Quarterly Journal of the Geol. Soc.*, vol. xiv., pp. 322–335. Being present at the meeting of the Geological Society (Jan. 21, 1857), when Prof. Prestwich's Paper was read, I had an opportunity of examining the shells: the second one was stated to be a Mya-like species. From certain characters it possessed, I felt certain, as I there and then expressed, that it belonged to the still-existing species named in the text.

more or less vertical position, is found to be resolvable into two or more directional series or systems, each being distinguished by uniform parallelism, also by a definite and an independent course, of its members. It is also found that these systems are traceable, as in the limestone districts of the west of Ireland, over areas hundreds of miles in extent; often, however, more developed in some places than in others, or suddenly disappearing here, and as suddenly setting in with great force elsewhere. The remarkable approximate parallelism of these systems with the meridians and the equator seems to give propriety to one being named meridional and the other equatorial.

That jointing ought to command the closest attention of engineers engaged on subaqueous works must now be evident. The following case is added, however, to make the statement still more obvious:—

During the famine period of 1845–1848 in Ireland, the Board of Public Works commenced the construction of a canal through beds of Carboniferous limestone for drainage purposes, and the opening out of a water communication between Loughs Corrib and Mask of about four miles in length. But, on nearly completing the work, it was found that the joints, well developed in the limestone, and probably taken to be little more than superficial, carried off all the water, necessitating much additional and unexpected outlay to remedy the defect. Thus after an expenditure, as I am credibly informed, of £40,000 of public money, what was intended to be a canal turned out to be nothing else than a dry ditch; and as such it still remains—a warning to all engineers not to neglect becoming acquainted with an important geological phenomenon.

Passing to the Channel Tunnel, it is true that this scheme has nothing to do with rocks in which jointing is so well developed as in the Carboniferous limestone and other Primaries. Still, with the facts that have been before us, together with others which are yet to be noticed, I feel confident the undertaking, if it ever be properly entered upon, will develop graver difficulties than any that have been conceived by those who are actively promoting it.

For anything known to the contrary, it may be safely assumed that the rocks to be penetrated by the tunnel are the sandstones, shales, and chalk formations, included in the Cretaceous and Neocomian Systems, known to exist in the counties that have been mentioned, also in the Bas Boulonnais on the opposite seaboard of France.

As stated before, these rocks in Kent and Surrey have been thrown into flexures, running axially in a nearly east and west direction; while parallel with them is a number of dislocations or faults, and fractures. A marked feature of the flexures is, that they are broken right across by transverse gorges, seen particularly where they are in the form of ridges, through which the main rivers flow into the Thames and its estuary on the north, and into the Channel on the south.

Different hypotheses have been offered in explanation of these east to west valleys and north to south gorges: the generally accepted one ascribes them to the mechanical forces which upheaved the wealden

anticlinal. I am more inclined to take the view that they were originally equatorial and meridional joints existing previously to the upheaval, some having been widened so as to resemble crevices, and others converted into the faults common in the district. This view[3] may be taken as strongly supported by the fact that jointing of both systems are to be seen within the area under consideration, occurring in beds that can only have been *slightly disturbed*. Near St. Leonards, one of the wealden members, lying below high-water mark, is distinctly divided by both meridional and equatorial jointing in its typical form; and, to all appearance, it seemingly has no more resulted from stratic disturbances than the corresponding structures so wonderfully developed in the nearly horizontal limestones in the Burren of Co. Clare.

On the opposite parts of France clear evidences occur in the chalk rocks of the same coincidences between jointing, faults, &c., highly calculated to give rise to serious apprehensions in connexion with the tunnel. M. Daubrée[4] has mapped the river-drainage of the district watered by the lower part of the Somme, which, it is well known, takes two main directions, approximately N.E. to S.W. and N.W. to S.E. He has also determined these bearings to be in parallelism with two systems of fracture referable to those of jointing.

If further evidences adverse to the Channel Tunnel be called for, I would urge anyone to consult M. Daubrée's figures and description of a long stretch of coast near Tréport, north of Dieppe, occupied by chalk-cliffs, crowded with vertical jointing belonging to the same intersecting systems; also to examine the "many small faults" and "very marked and constant joints" which characterize the chalk-cliffs in many places near Margate,[5] and the "numerous nearly vertical crevices" intersecting a bed of chalk fifty feet thick *close to Dover*, at the base of Shakespeare's Cliff.[6]

The cases above noticed are sufficient to show the strong probability that the chalk rocks to be penetrated are more or less affected by sources of water leakage: indeed it may be contended that, what with inclined bedding partings, *faults, disruptive fractures, true jointing*, swallow holes and *rock-porosity*, the engineers of the Channel Tunnel will have a serious work in hand.

That the tunnelling of the Strait of Dover is expected to bring out adverse contingencies is evidently anticipated, as some of the engineers have proposed to line the work with blocks of concrete, formed of chalk on the spot, and gravel from a distance. But it is extremely doubtful that this material would have sufficient strength, or power of resist-

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[3] Prof. Haughton, M. Daubrée, and others, take the mechanical view as to the origin of jointing. Prof. Phillips (whom I follow) leaned to what may be called the physical view.

[4] Études Synthétiques de Géologie, prem. partie, 324–326, 360.

[5] W. Whitaker, *Q. J. Geol. Soc.*, vol. xxi., p. 396.

[6] W. Phillips, *Trans. Geol. Soc.*, 1st S., vol. v., p. 34.

ance, to withstand the force and action of the water circulating through all the leakages that may be expected. I would, therefore, urge, as absolutely necessary, should the tunnel be undertaken, that it be lined throughout with masonry consisting of squared blocks of the most resisting, impervious, and endurable stone. Obviously, however, this cannot be done except at an enormous expense—a matter which may be safely left to be considered by capitalists.

LXXIX.—Report upon the Botany of the Macgillicuddy's Reeks, Co. Kerry. By H. C. Hart.

[Read, April 24, 1882.]

On the 13th July, 1881, I reached Glencar Hotel, at the western extremity of the Reeks. This hotel, upon the banks of the river Caragh, is a favourite resort for anglers; and a better head-quarters for those who are in search of mountain scenery could not be selected in Ireland. From here I frequently traversed the whole length of the range, making my way into Killarney at night, and returning over the mountains in another route the following day. I spent fifteen days amongst the Reeks, and, by using cars or boats as much as possible below, I passed most of those days high up amongst the numerous alpine cliffs and ridges, or in the neighbourhood of some of the mountain tarns.

The Reeks stretch from their eastern extremity at the Gap of Dunloe to the end of the Beenbane spur, above the road from Glencar to Cloon Lake, a distance of about ten miles west from the Gap. The road from Glencar to the Gap is a northern boundary, while the Black Valley, and the valley of the Caragh define the southern limits of the range.

From Lake Auger in the Gap of Dunloe a series of precipitous bluffs carries us up at once to a height of nearly 2000 feet, which goes on increasing along a serrated ridge till it reaches 3000 feet above Lough Cummeenapeasta, about two and a-half miles west of the Gap. This ridge can be traversed then for the whole extent of the range, and forms the grandest bit of mountaineering to be met with in Ireland. For several miles it maintains an altitude of about 3000 feet, sometimes narrowing into a jagged knife-edge, and here and there descending abruptly into some of the numerous lakes nestled amongst the precipices below. Upon reaching the highest point, Carran Tuohill, 3414 feet, a northern branch extends to Beenkeragh, 3314 feet, and to Skregmore, 2790 feet; while the axis proper carries us on by Caher, 3200 feet, and Curraghmore, 2680 feet, down to the head of Cummeenacappul, where lies a gap in the ridge, which forms a connexion between Cummeenacappul on the one side and the valleys of Caragh and Cummeenduff ("Black Valley") on the other or south side. This gap is perhaps the proper western extremity of the Reeks; it lies, however, at about 1000 feet above sea level, and the Beenbane spur rises again from it to the westward, finally descending to a low level at the river Caragh. The latter appeared, therefore, the more natural boundary.

The Reeks are composed for the most part of hard green and purple grits, and sandstones of the geological formation of Old Red Sandstone age. In consequence of the firmness of these rocks, the

numerous ranges of cliffs are safe to climb amongst, and there are few points available for alpine plants that I did not succeed in examining.

There are several lakes in the Reeks; thirteen fall within the bounds above laid down. Some of these are at considerable altitudes, as Cummeenoughter (the "Devil's Looking-glass") at 2338 feet, and Cummeenapeasta at 2156 feet; while, by including Lake Acoose at 500 feet, we have means of comparison at various heights for about 2000 feet of the altitudes at which different aquatic plants can exist. All these lakes I examined; but the chief haunts of the alpine plants in the Reeks lie, as a rule, at higher altitudes than even the uppermost of these lakes. No general rule, except that of height, would guide a botanist to the rarer plants; they occur upon cliffs with various aspects, at both northern and southern sides of the chain. Absence of the direct influence of strong sunlight, with moisture, and a sufficiency of cliffs, enable alpine plants to descend to a level more than usually low, as on the cliffs above Lake Auger in the Gap of Dunloe. These latter are amongst the worst, though at the same time most attractive, cliffs, to climb throughout the Reeks. It will be found, however, that lowland plants ascend to a more considerable height upon the southern than upon the northern flanks of the range. I estimated this difference at a rough average of about 500 feet.

The most inviting ground for a botanist lies perhaps amongst the cliffs south of Lough Eagher, at the head of Cumloughra. There is, however, a high valley, or rather series of coombs, to the north of Lough Googh, which is more alpine in its botanical facies than any other point of the Reek. Most of the alpine plants of the range grow here to perfection, while numerous grottos shelter a luxuriant growth of ferns, which are, I think, inaccessible enough to be tolerably safe from the depredation of collectors. A good colony of holly fern was here discovered, while green spleenwort and brittle fern are everywhere abundant.

The variable *Draba incana* is also to be gathered here, and several saxifrages are very common. The amphitheatre of cliffs around the "Devil's Looking-glass" is attractive ground for explorations also. In the upper margin of these precipices *Aira caespitosa*, var. *alpina*, a viviparous form, not previously recorded in Ireland, but known on the Scottish Highlands, is frequent.[1] I have gathered this form also upon Baurtregaum in the Slieve Mish range, west of Tralee, at 2200 feet, and upwards. From the crest of these cliffs westward, above the "Looking-glass," the view obtained, as one looks across the lonely tarn below, through a vista opening up the Hag's Glen, and its towering precipices surrounding its two lakes, stretching far eastward amongst heights and peaks across a broad valley, to be closed up

[1] See under *Aira* at 3100 feet, *post*.

again by the lofty summit of Cummeenapeasta against the sky, is one which I have never seen surpassed in grandeur and beauty combined.

The highest altitude at which I observed cultivation was at about 800 feet in the Hag's Glen, and 730 feet in Cummeenacappul on its western side. But, while the base of the chain is mountainous in character and undoubtedly part of the mass of mountains forming the Reeks, it seems unadvisable to set an artificial downward limit to my enumeration of the flora of the chain. There is so interesting a lowland flora in Kerry, that it seemed to me quite as important to note how these species below were checked in their distribution on its flanks by a mountain chain, as to study the range of the plants amongst the mountains themselves.

I have used, in my appended catalogue, the names of places as given in the Ordnance Map. These are very scanty, so that I have given the summits above the Lakes Cummeenmore, 3141 feet, and Cummeenapeasta, 3062 feet, the names of these lakes respectively. In adopting the names to be found on the Ordnance Maps, I did what appeared to be necessary for purposes of reference; but the local names are often quite different, and frequently the names on the Map were quite unknown in the country. One advantage the Maps of this district possess, namely, the levels above the sea of the mountain lakes, which are given on the Six-inch Survey. In order to show that aneroid observations are sufficiently reliable, I append a list of the heights of these lakes, as estimated by me on the spot, with those recorded by the survey afterwards taken down in Dublin:—

	Aneroid.			Survey.
Lake	Googh,	1600 feet above sea level,	. .	1590.
,,	Callee,	1100 ,, ,,	. .	1095.
,,	Gouragh,	1150 ,, ,,	. .	1126.
,,	Curraghmore,	1000 ,, ,,	. .	1004.
,,	Cummeenoughter,	2400 ,, ,,	. .	2338.
,,	Cumloughra,	1550 ,, ,,	. .	1553.
,,	Eighter,	1500 ,, ,,	. .	1424.
,,	Acoose,	500 ,, ,,	. .	507.

The district examined yielded in all 220 species; of these the following ten alpine plants belong to Watson's Highland type:—

Draba incana.
Sedum Rhodiola.
Hieracium anglicum.
Oxyria reniformis.
Salix herbacea.
Carex rigida.
Polystichum Lonchitis.
Asplenium viride.
Isoetes lacustris.

To these may be added the following sub-species:—

Armeria alpina,
Cochlearia alpina,
Aira alpina,

and *Lycopodium alpinum*, which Mr. More informs me he has gathered upon the Reeks, but which I failed to notice.

Considering the extent of elevated cliffs, the above is a poor alpine flora. The northern or Scottish type plants are, considering the latitude, at least as well represented; these are:—

Subularia aquatica.
Saxifraga hirta.
Antennaria dioica.
Lobelia Dortmanna.
Empetrum nigrum.
Carex limosa.

As might be expected, from the western situation, several of Watson's Atlantic type plants find their way up the slopes of the Reeks, as—

Sedum anglicum.
Cotyledon umbilicus.
Carum verticillatum.
Bartsia viscosa.
Pinguicula lusitanica.
Euphorbia hyberna.
Scirpus savii.
Hymenophyllum tunbridgense.
H. Wilsoni.

The undermentioned species are peculiarly interesting as not being native in Great Britain:—

Saxifraga geum.
S. umbrosa.
S. hirsuta.
Arbutus Unedo.
Pinguicula grandiflora.
Trichomanes radicans.

The following are rare plants in Kerry, for which I discovered new localities on the Reeks:—

Thalictrum minus.
Subularia aquatica.
Elatine hexandra.
Filago minima.
Antennaria dioica.
Hieracium anglicum.
Empetrum nigrum.
Salix herbacea.
Malaxis paludosa.
Sparganium natans.
Carex limosa.
Polystichum Lonchitis.

As these are the highest mountains in Ireland, I recorded the ranges of plants with much care, and repeated corroboratory checks. I mention this lest it be thought my notice of altitudes is given too profusely.

Further, I purposely refrain from making any general statements with regard to mountain botany, or remarks of comparison with other Irish ranges, until better enabled to do so by a more complete experience.

I wish here to make a remark upon the saxifrages: Having submitted a series to Mr. Baker, of Kew, he refers all the *S.*

hypnoides forms to *S. hirta*, Sm. This plant is very variable, and occurs in two well-marked forms, the typical plant occurring at greater heights, and usually in more alpine situations and amongst alpine neighbours. Specimens from Baurtregaum, on the Slieve Mish range Mr. Baker has called *S. affinis*, Don. It is quite indistinguishable from the plant of the Reeks; but bears sometimes a close resemblance to *S. cæspitosa*, Linn. Unfortunately an inversion of names appeared in my "Report[2] on the Botany of the Galtee Mountains." I have there said that *S. platypetala* is the form usually met with in wetter mossy places at low levels by streams; "while *S. hirta*, var. *genuina*, the finest cut form with bristle-pointed leaves, is especially characteristic of the bases of the loftier cliffs." These names should be transposed. *S. platypetala* of the Galtees, this finest leaved form, is very distinct in appearance, more so, I think, than any of the others; it is named *S. sponheimica*, Gm., by Baker, and I have only met with it upon the Galtees.

With regard to the *S. umbrosa* forms; as we travel westward *S. geum* becomes more prevalent. On the Galtees *S. umbrosa* alone occurs; on the Reeks *S. umbrosa* is most abundant; but *S. geum* is frequent, while *S. hirsuta* occurs. *S. geum*, however, never ascends to any great height on the Reeks, finding its upper limit at 1650 feet in Cumloughra, while *S. hirsuta* is quite lowland. On the Slieve Mish Mountain, west of Tralee, *S. geum* prevails at 2500 feet, and is abundant.

GENERAL LIST OF PLANTS

Observed on the MACGILLICUDDY'S REEKS, *arranged in descending order.*

SUMMIT OF CARRAN TUOHILL.

3414 feet.

Galium saxatile (Linn.)—On all the summits, and downwards.
Vaccinium Myrtillus (Linn.)—On all the summits, and downwards.
Armeria maritima (Willd.)—Occurs on all the highest points commonly, and reaches downwards to 1900 feet on the cliffs of Caher, S.W. from Cumloughra; and 1000 feet on the muddy shore of Curraghmore lake.
Rumex Acetosa (Linn.)—On all the summits, and downwards.
R. acetosella (Linn.)—Not so common as the last; occurs again at 3070 feet, S.W. from Lough Cummeenapeasta, and elsewhere.
Luzula sylvatica (Bichen.)—With the last, and on the summit above Lough Cummeenmore at 3070 feet; decreases at 2000 feet, and scarce lower than 1500 feet in Cumloughra.

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[2] These *Proceedings*, *antea* p. 392.

Aira flexuosa (Linn.)—Common at all heights.
Agrostis vulgaris (With.)—Common at all heights.

Carran Tuohill (North Side).

3400 feet.

Saxifraga stellaris (Linn.)—Occurs on Caher at 3100 feet, north side; reaches to 1050 feet on Bull's Mountain, and finds its lowest limit at 750 feet by the stream in Cummeenacappul.

3370 feet.

Saxifraga umbrosa (Linn.)—Universally distributed; see introductory remarks.

Summit of Beenkeragh.

3300 to 3314 feet.

Empetrum nigrum (Linn.)—From 3000 feet to the summit; does not occur on the Carran Tuohill or Caher heights. It ranges across the Hag's Glen to Cummeenapeasta, where it is very abundant, and the neighbouring heights, finding its lowest limit at 1700 feet on the east side of the Glen. It occurs also on the Gap from the Hag's Glen to Curraghmore Lake, and at the Hag's Tooth.

Calluna vulgaris (Salisb.)—The upper part of Carran Tuohill, though containing suitable soil, appears to be above the vertical limit of this plant; it was very stunted in the present station, and at Cummeenmore (3140 feet) it was dwarfed and dead. It struggles up to 3250 feet on Carran Tuohill.

Festuca duriuscula (Linn.)—Also at 3140 feet on Cummeenmore; viviparous at 3100 feet on Caher.

Juncus squarrosus (Linn.)—Up to 3000 feet on Caher.

Carex stellulata (Good.)—3050 feet on Caher; 3000 feet down Cummeenapeasta.

Hymenophyllum Wilsoni (Hook.)—This fern is very abundant, forming carpets amongst the loose boulders on the summit of Beenkeragh; at 2900 feet on the Caher cliffs, S. W. from Cumloughra, and frequent at lower heights.

Carran Tuohill (S. W. Side).

3230 feet.

Thymus Serpyllum (Linn.)—Very common from about 3000 feet downward, especially about Cumloughra; at 3100 feet on Beenkeragh.

3200 feet, N. W. side.

Viola sylvatica (Bab.)—Occurs up to 3100 feet on the north side of Caher.

Leontodon autumnalis (Linn.)—In small quantity at this unusual height; again at 2690 feet, S. W. side of Carran Tuohill, and 2250 feet in Cumloughra.

CLIFFS ABOVE LOUGH CUMMEENOUGHTER (THE "DEVIL'S LOOKING-GLASS") ON CARRAN TUOHILL.

3150 feet.

Saxifraga hirta (Sm.)—(var. *genuina*)—The commonest form amongst the upper cliffs, and occurring downwards as far as Lake Eighter, 1500 feet. This latter is the lower limit of all forms of the present species. See introductory remarks.

Sedum Rhodiola (D.C.)—Frequent, and occurring at 1200 feet, its lower limit on Bull's Mountain, above Lake Auger, in the Gap of Dunloe; 2900 feet on Cummeenapeasta; 2850 feet on Caher. Ceases at 1700 feet above Lough Curraghmore.

Melampyrum pratense (Linn.)—(var. *montanum*)—And at 3120 feet on the south side of Caher; at 3100 feet on Carran Tuohill and Beenkeragh, &c.

Oxyria reniformis (Hook.)—In most of the upper gullies; to 1650 feet in Cumloughra; and 1500 feet on Mount Brassel, above Lake Callee.

Cystopteris fragilis (Bernh.)—Very luxuriant above Lake Googh at about 2500 feet; and in Cumloughra at 1400 feet above Lake Curraghmore on cliffs looking south; disappears here as a mountain plant.

Lastræa Filix-mas (Presl.)—A stunted mountain form, is frequent at the head of the Hag's Glen; Caher, 2850 feet; Cumloughra, 2400 feet.

Blechnum boreale (Sw.)—Not frequent till about 2800 feet.

Asplenium viride (Huds.)—At 2850 feet above Cumloughra; lower limit at 1850 feet in Cumloughra. Remarkably luxuriant in the coombs above Lough Googh; a common plant at a sufficient height on the Reeks.

CARRAN TUOHILL (S.-W. SIDE).

3120 feet.

Potentilla Tormentilla (Schenk.)—And at 3000 feet on Caher; abundant from that height downwards.

CAHER (SOUTH SIDE.)

3120 feet.

Campanula rotundifolia (Linn.)—At 3100 feet at the head of the Hag's Glen; frequent from two to three thousand feet in Cumloughra; disappears at 1800 feet above Lough Curraghmore.

Luzula campestris (D. C.)—Again at 2850 feet, Cumloughra; not unfrequent.

Carex pilulifera (Linn.)—And at 2350 feet, Cumloughra; 800 feet in Cummeenacappul; not common.

Nardus stricta (Linn.)—Occurs also at 2690 feet on S.-W. side of Carran Tuohill; common below that.

CARRAN TUOHILL (NORTH SIDE).

3100 feet.

Cochlearia officinalis (Linn.)—Var. *alpina;* in gullies above Cummeenoughter; lower limit at Cumloughra Lake level, 1550 feet.

Aira cæspitosa (Linn.)—var. *vivipara; A. alpina* (Linn.)—This form is well marked at the present height and all around the cliffs at about 2700 to 2800 feet above Cummeenoughter to Beenkeragh; at the level of the Devil's "Looking-glass" (2350 feet) it is found in an intermediate stage, and, travelling still downwards, we find normal *A. cæspitosa* immediately below by the shores of Lough Gouragh, at 1150 feet. In A. G. More's "Recent Additions to the Flora of Ireland" he records *A. cæspitosa*, "which, except that the florets are not viviparous, Dr. Syme considers indistinguishable from the Scottish *A. alpina;* grows near the summit of Carn Tual." I found it commonly viviparous, and constantly so at its upper limit. Mr. Baker refers to it *A cæspitosa*, var. *vivipara*. It is, no doubt, identical with the Scotch plant.

RIDGE BETWEEN LAKE CURRAGHMORE AND LAKE CUMMEENAPEASTA.

3070 feet.

Luzula multiflora (Lej.)—Common downwards.

RIDGE BETWEEN CARRAN TUOHILL AND BEENKERAGH.

3050 feet.

Jasione montana (Linn.)—Becoming frequent at about 2600 feet in Cumloughra.

Carex rigida (Good)—Frequent from 2900 to 2300 feet above Cumloughra; lower limit at 2100 feet in Cumloughra.

SUMMIT ABOVE LAKE CUMMEENAPEASTA.

3050 feet.

Salix herbacea (Linn.)—At 3000 feet on the north side of Caher; plentiful on the cliffs between Caher and Cumloughra, from 2700 to 2350 feet, below which I did not meet with it. Frequent along the ridge between Cummeenapeasta and Curraghmore lakes, and on Carran Tuohill at the northern side.

Lycopodium Selago (Linn.)—Frequent to about 2300 feet; lower limit at 1850 feet above Cumloughra.

CARRAN TUOHILL (S.-W. SIDE).

3030 feet.

Anthoxanthum odoratum (Linn.)—Again at 2850 and 2450 feet in Cumloughra; and then becoming frequent.

RIDGE ABOVE CUMMEENAPEASTA LAKE.

3000 feet.

Cerastium triviale (Link.)—At 2610 feet on Caher; then frequent.
Solidago Virga-aurea (Linn.)—At 2776 feet above L. Curraghmore; frequent in Cumloughra, &c.
Lastrea dilatata (Presl.)—At 2350 feet, close to the lake, in Cummeenoughter; at 2100 feet in Cumloughra, and then becoming frequent.

2950 feet.

Ranunculus acris (Linn.)—At 2850 and 2450 feet, Cumloughra; and then frequent.

CLIFFS BETWEEN CAHER AND CUMLOUGHRA.

2940 feet.

Cardamine pratensis (Linn.)—At 2550 feet S.-W. side of Carran Tuohill, and at 2450 feet, Cumloughra.

2900 feet.

Antennaria dioica (Gœrt.)—Very rare; only a few plants noticed.

CARRAN TUOHILL (S.-W. SIDE).

2880 feet.

Euphrasia officinalis (Linn.)—And from about the same height on Caher; common.

RIDGE BETWEEN CAHER AND CARRAN TUOHILL.

2850 feet.

Asplenium Trichomanes (Linn.)—This fern is scarce at any considerable altitude in the Reeks; it is more frequent in the Gap of Dunloe on the Bull's Mountain than elsewhere.

S.-EASTERN SIDE OF CARRAN TUOHILL, ABOVE L. CURRAGHMORE.

2800 feet.

Orchis maculata (Linn.)—Not met with elsewhere at any great height.

Summit N.-E. from L. Curraghmore.

2776 feet.

Eriophorum vaginatum (Linn.)

Cliffs S.-W. from Cumloughra.

2610 feet.

Angelica sylvestris (Linn.)—Afterwards not unfrequent; 2550 feet above Lough Googh.

Polypodium vulgare (Linn.)—Common below.

Carran Tuohill (S.-W. Side).

2550 feet.

Ranunculus repens (Linn.)—Rare at great heights; 2450 feet on Caher.

Viola palustris (Linn.)—2200 feet above Lake Googh; frequent at lower levels.

Carex flava (Linn.)—Common at lower levels, from 2300 feet downwards.

Cliffs North of Lake Googh.

2550 feet.

Draba incana (Linn.)—And at 2470 to 2380 feet on cliffs looking south between Cummeenmore and the Black Valley. In two distinct gullies here, and not scarce in a limited space above L. Googh. Only occurs on the south side of the Reeks. Varies much in hairiness, incision of leaves, etc.

Cardamine hirsuta (Linn.)—Again at 1390 feet in the central gully from Cumloughra; not at greater altitudes.

Stellaria media (With.)—Not met with elsewhere at any great height; 975 feet, Beenbane.

Veronica Chamædrys (Linn.)—Again at 2470 feet on the southern side of Cummeenmore, and 1950 feet in Cumloughra.

Poa annua (Linn.)—Again at 2250 feet on the southern side of Cummeenmore, and at 2400 in Cummeenoughter.

Carex binervis (Sm.)—And at 2470 feet in Cummeenoughter; common below.

C. panicea (Linn.)—An unusual height for this sedge; 1850 feet, Cumloughra.

Polystichum Lonchitis (Roth.)—I discovered a colony of well-grown plants of the holly fern in a tolerably safe position here. I trust any future visitor will disturb it as little as I did. This, one of the rarest Irish ferns, grows also sparingly on Mangerton and Brandon in Kerry. Elsewhere in Ireland it occurs only on the Ben Bulben and Glenade ranges.

CLIFFS ABOVE CUMMEENOUGHTER ("DEVIL'S LOOKING-GLASS.")

2500 feet.

Hieracium anglicum (Fries.)—At 2080 feet, cliffs south of Cummeenmore; in Cumloughra and on Bull's Mountain in several places, and finding its lowest limit on the Bull's Mountain cliffs above Lake Auger in the gap of Dunloe at 1100 feet; not previously recorded from the Reeks.

CAHER, ABOVE CUMMEENACAPPUL.

2500 feet.

Erica cinerea (Linn.)—A small isolated patch of heather occurs on the southern brow of the ridge between Curraghmore and Caher; as a feature in the vegetation it ceases upwards here at 2200 feet. Ceases at 2200 feet on Cummeenmore; at 2150 feet, Bull's Mountain; at 1950 feet, Cumloughra, and at 1700 feet above L. Curraghmore.

CARRAN TUOHILL (S.-W. SIDE).

2480 feet.

Chrysosplenium oppositifolium (Linn.)—And at 2470 feet, south side of Cummeenmore; then frequent.

CUMMEENMORE, SOUTH CLIFFS ABOVE CUMMEENDUFF (BLACK VALLEY.)

2470 feet.

Taraxacum Dens-Leonis (Drof.)—And at 2250 feet and 1950 in the central glen from Cumloughra.

Polystichum aculeatum (Roth.)—And at 900 feet in Cummeenacappul; scarce.

CARRAN TUOHILL (S.-W. SIDE).

2440 feet.

Polygala depressa (Wend.)—True *P. vulgaris* occurs at 2400 feet at the "Devil's Looking-glass."

Hypericum pulchrum (Linn.) } Again at 2200 feet on south side of Cummeenmore Mountain.

Pedicularis sylvatica (Linn.) } Soon becoming common.

SOUTH SIDE OF CUMMEENMORE.

2380 feet.

Carex pulicaris (Linn.)—Also at 1800 feet above Lough Curraghmore; rather scarce.

Rhinanthus crista-galli (Linn.)—And at 1500 feet, Bull's Mountain, above the Gap of Dunloe.

CUMMEENMORE, BY THE LAKE.

2350 feet.

Ranunculus Ficaria (Linn.)—And at 2250 and 1950 feet in Cumloughra.

2338 feet (Ordnance height.)

Isoetes lacustris (Linn.)—And in Lake Eighter, 1500 feet.

CLIFFS S.-W. FROM CUMLOUGHRA.

2300 feet.

Pyrus Aucuparia (Linn.)—A solitary seedling. Again at 1360 feet on Beenbane; scarce on the Reeks.

SOUTH SIDE OF CUMMEENMORE.

2300 feet.

Stellaria uliginosa (Murr.)—And at 1553 feet, level of lakes in Cumloughra; frequent below this last height.

HEAD OF CUMLOUGHRA.

2300 feet.

Athyrium Filix-fœmina (Roth.)—Not elsewhere at any considerable height.

2250 feet.

Oxalis Acetosella (Linn.)—Becoming frequent at about 1800 feet.
Digitalis purpurea (Linn.)—At the same height on the southern side of Cummeenmore; not frequent for about a thousand feet down.
Molinia cærulea (Mænch.)—Not abundant for about seven hundred feet lower down.
Juncus conglomeratus (Linn.)—Frequent in upper valleys.

ABOVE LAKE CUMMEENMORE.

2250 feet.

Pinguicula grandiflora (Lam.)—I gathered this beautiful plant in flower at this height, and again at 1780 feet in the Hag's Glen.

SOUTH SIDE OF CUMMEENMORE MOUNTAIN.

2250 feet.

Veronica officinalis (Linn.)
Primula vulgaris (Linn.)
} Several lowland plants reach an unusual height on this southern face of the Reeks above the Black Valley. Primrose occurs again at 1850 feet, Cumloughra; *Veronica officinalis* at 1063 feet above Curraghmore Lake.

2200 feet.

Ulex Gallii (Planch.)—Also at 2000 feet on Caher above Cummeenacappul, 1350 feet in the Hag's Glen, and 1480 on Beenbane; quite unusual heights for the dwarf furze.

Spiraea Ulmaria (Linn.)
Plantago lanceolata (Linn.)
Juncus articulatus (Linn.)

See under *Primula vulgaris*. *Plantago lanceolata* occurs at 1800 feet above L. Curraghmore. *Spiræa Ulmaria* at 1350 feet above Curraghmore Lake.

HEAD OF CUMLOUGHRA.

2150 feet.

Poa pratensis (Linn.)—Scarce.

NORTH OF LOUGH GOOGH.

2100 feet.

Alchemilla vulgaris (Linn.)—Scarce; at 1400 feet on Beenbane.
Aira cæspitosa (Linn.)—See under *A. alpina* at 3100 feet above. At 2080 feet on the south side of Cummeenmore Mountain.
Lastræa æmula (Brack.)—A remarkable altitude for this fern; occurs also at 1340 feet above Lake Cummeenmore.

CLIFF AT S. W. OF CUMLOUGHRA.

2100 feet.

Pinguicula vulgaris (Linn.)—Again at 1750 feet in the Hag's Glen. It is very unsafe to attempt to distinguish this plant from *P. grandiflora* when not in flower.

SOUTH SIDE OF CUMMEENMORE MOUNTAIN.

2080 feet.

Thalictrum minus (Linn.)—At 1500 feet on Mt. Brassel, above Callee Lake, and in several places from 1400 feet to 980 feet on Bull's Mountain above the Gap of Dunloe.
Hypericum Androsæmum (Linn.)—An unusual altitude for this plant to be found at; in one place only. See remarks under *Primula vulgaris* at 2200 feet.

CAHER, ABOVE CUMMEENACAPPUL.

1950 feet.

Erica tetralix (Linn.)—Finds its upper limit at 1750 feet in Cumloughra; at 1550 feet on Cummeenapeasta, in the Hag's Glen, and at 1650 feet above Lake Curraghmore.
Carex glauca (Scop.)—Again at 1650 and 1550 feet, Cumloughra, &c.

HEAD OF CUMLOUGHRA.

1950 feet.

Montia fontana (Linn.)—Again at 1780 feet by Lough Cummeenmore; and 1650, Cumloughra.

ABOVE LAKE CURRAGHMORE (TO THE NORTH-EAST.)

1800 feet.

Lysimachia nemorum (Linn.)—Again at 1780 feet by Lough Cummeenmore.

CARRAN TUOHILL (ABOVE CUMLOUGHRA).

1800 feet.

Aira præcox (Linn.)

LAKE CUMMEENMORE.

1780 feet.

Veronica serpyllifolia (Linn.)—At 1650 feet in Cumloughra.
Myriophyllum alterniflorum (D. C.)—At 1250 feet in Lough Callee, Mount Brassel; 1000 feet, Lake Curraghmore.

ABOVE LAKE CURRAGHMORE (TO THE NORTH-EAST).

1700 feet.

Pteris aquilina (Linn.)—At 1650 feet, Cumloughra; 1550 feet, Cummeenapeasta and Skregmore.

CUMLOUGHRA (AT S.-W. END).

1650 feet.

Saxifraga Geum (Linn.)—At 1150 feet on the Bull's Mountain, Gap of Dunloe; at 1090 feet, Breenbane. *S. hirsuta* occurs also near the lakes in Cumloughra, and in Glencaragh at about 700 feet. See introductory remarks.
Poa trivialis (Linn.)

HAG'S TOOTH.

1650 feet.

Agrostis alba (Linn.)

LAKE GOOGH.

1600 feet.

Potamogeton pusillus (Linn.)

CUMLOUGHRA LAKE LEVEL.

1550 feet.

Ranunculus Flammula (Linn.)
Sagina procumbens (Linn.)
Scabiosa succisa (Linn.)
Galium palustre (Linn.)
Narthecium ossifragum (Huds.)
Juncus acutiflorus (Ehrb.)
Glyceria fluitans (Brown.)

These, with most of the other lowland plants already mentioned, occur more freely now. The alpine flora has almost entirely disappeared.

HAG'S GLEN (ON CUMMEENAPEASTA).

1550 feet.

Prunella vulgaris (Linn.)—And at 1200 feet, head of Glencaragh.

BULL'S MOUNTAIN (ABOVE THE GAP OF DUNLOE).

1500 feet.

Asplenium Adiantum-nigrum (Linn.)

FINGLAS RIVER VALLEY.

1470 feet.

Ulex europæus (Linn.)
Lonicera Periclymenum (Linn.)

BEENBANE.

1450 feet.

Menyanthes trifoliata (Linn.)

LAKE EIGHTER (AT ENTRANCE TO CUMLOUGHRA.)

1425 feet.

Lychnis Flos-cuculi (Linn.)
Epilobium palustre (Linn.)
Litorella lacustris (Linn.)—At 1000 feet, Lake Curraghmore.
Sparganium minimum (Fries.)—And at 1250 feet, Lake Callee, Mount Brassel.
Eriophorum polystachyum (Linn.)—Upper limit at same height on Beenbane.
Equisetum limosum (Linn.)

STREAM OUT OF LAKE EIGHTER.

1400 feet.

Sedume anglicum (Linn.)

Bull's Mountain above Lake Auger in the Gap of Dunloe.

1400 feet.

Silene maritima (With.)—Not met with elsewhere on the Reeks.

Above Lake Cummeenmore.

1380 feet.

Hedera Helix (Linn.)
Chærophyllum silvestre (Linn.)
Bellis perennis (Linn.)
Betula alba (Linn.)
Salix caprœa (Linn.)

Above Lake Curraghmore.

1350 feet.

Trifolium repens (Linn.)
Salix aurita (Linn.)

Mount Brassel (South Side).

1350 feet.

Ajuga reptans (Linn.)—And at 820 feet in Glencaragh.

Hag's Glen.

1350 feet.

Ilex aquifolium (Linn.)—The finest hollies I have ever seen grow in a grove farther down the glen by the Gaddagh River.

Cummeenacappul.

1350 feet.

Lathyrus macrorrhizus (Winn.)—Scarce: at 550 feet, near Lake Acoose.

By the River Finglas.

1340 feet.

Euphorbia hyberna (Linn.)—At 1200 and 950 feet in Cummeenacappul; common lower down.

Cummeenacappul.

1300 feet.

Salix cinerea (Linn.)—Very scarce and stunted.

LOUGH CALLEE, MOUNT BRASSEL.

1250 feet.

Subularia aquatica (Linn.)—And in Lake Acoose, 507 feet at the northern side.
Lobelia Dortmanna (Linn.) — And in most lower lakes, Acoose, Googh, &c.
Potamogeton natans (Linn.)—And at 1100 feet, Lough Calle, Hag's Glen.
Carex paniculata (Linn.)—At 975 feet, Beenbane; and 740 feet, Lake Curralee.

WATERSHED, BETWEEN RIVERS CARAGH AND CUMMEENDUFF.

1200 feet.

Centaurea nigra (Linn.)
Teucrium scorodonia (Linn.)
Schœnus nigricans (Linn.)—At 1100 feet on Feabrahy.
Triodia decumbens (Beauv.)—At about the same height in Cummeenacappul.
Dactylis glomerata (Linn.)

LOUGH GOURAGH, HAG'S GLEN.

1126 feet.

Elatine hexandra (D.C.)—On the northern margin of the lake.
Callitriche hamulata (Kutz.)—*C. verna* at 1000 feet, Lake Curraghmore.

BULL'S MOUNTAIN.

1100 feet.

Rubus carpinifolius (W. & N.)

ABOVE LAKE CURRAGHMORE.

1100 feet.

Vicia sepium (Linn.)

SKREGMORE.

1100 feet.

Myrica gale (Linn.)

1050 feet.

Drosera rotundifolia (Linn.)—1010 feet on Beenbane; 1000 feet, east from Lough Acoose.
Rhynchospora alba (Vahl.)

LAKE CURRAGHMORE LEVEL.

1000 to 1010 feet.

Myosotis repens (Don.)
Senecio sylvaticus (Linn.)
Polygonum Hydropiper (Linn.)
Juncus supinus (Mœnch.)
J. bufonius (Linn.)
Holcus lanatus (Linn.)
Aira caryophyllea (Linn.)
Hymenophyllum tunbridgense (Sm.) — Forming dense and beautiful carpets amongst large boulders by the north-eastern margin of the lake; 800 feet in Cummeenacappul.

WEST SIDE OF CUMMEENACAPPUL TO BEENBANE.

975 feet.

Anagallis tenella (Linn.)
Hypericum elodes (Linn.)

BY STREAM FROM LOUGH GOOGH.

970 feet.

Pinguicula lusitanica (Linn.)—At 950 feet, east of Lake Acoose. Very scarce on the Reeks.

ABOVE LAKE ACOOSE.

950 feet.

Carex præcox (Jacq.)

CUMMEENACAPPUL.

950 feet.

Sonchus oleraceus (Linn.)

BULL'S MOUNTAIN.

940 feet.

Cotyledon Umbilicus (Linn.)

BETWEEN LAKE ACOOSE AND CUMLOUGHRA.

850 feet.

Drosera anglica (Huds.)

HAG'S GLEN.

850 feet.

Cratægus Oxyacantha (Linn.)—50 feet below this, cultivation first appears.

By the Stream from Lough Googh.

850 feet.

Scirpus Savii (S. & M.)—Not seen elsewhere.

By Source of River Caragh, East of Maghanlavaun (Brida.)

850 feet.

Corylus Avellana (Linn.)
Brachypodium sylvaticum (R. & S.)

820 feet.

Osmunda regalis (Linn.)

Cummeenacappul (West Side).

800 feet.

Lotus corniculatus (Linn.)
Sanicula europæa (Linn.)

Lake Curraleе, on Benbane.

Nymphæa alba (Linn.)
Nuphar lutea (Linn.)
Comarum palustre (Linn.)
Hydrocotyle vulgaris (Linn.)
Scutellaria minor (Linn.)
Utricularia vulgaris (Linn.)
Malaxis paludosa (Sw.)—By the spongy margin of the lake in small quantity. This rare little orchid has been gathered in Kerry before.
Sparganium natans (Linn.)
Scirpus fluitans (Linn.)
Carex vulgaris (Fries.)
C. limosa (Linn.)—Forming a fringe around the edge of the lake. This rare and graceful sedge has been gathered in one place in Kerry previously.
C. ampullacea (Good.)

Cummeenacappul.

720 feet (cultivation appears in patches.)

Ranunculus hederaceus (Linn.)
Carduus lanceolatus (Linn.)
Gallopsis Tetrahit (Linn.)
Rumex obtusifolius (Linn.)
Atriplex patula (Linn.)

NORTHERN BASE OF SKREGMORE AND SKREGBEG.

700 feet.

Carum verticillatum (Koch.)
Bartsia viscosa (Linn.)

These two characteristic Kerry plants occur frequently from about the present height downwards all round the northern slope of the Reeks, by the western extremity, and into the valley of the river Caragh on their south. Their range is very similar and decided.

CUMMEENACAPPUL (WEST SIDE).

650 feet.

Hieracium Pilosella (Linn.)
Carex ovalis (Good.)

550 feet.

Viola tricolor (Linn.)
Pedicularis palustris (Linn.)
Veronica scutellata (Linn.)
Mentha aquatica (Linn.)
Sparganium ramosum (Huds.)

ABOVE LAKE ACOOSE.

550 feet.

Quercus Robur (Linn.)
Potamogeton polygonifolius (Pourr.)

BY THE STREAM FROM LOUGH GOOGH INTO BLACK VALLEY.

520 feet.

Arbutus Unedo (Linn.)—One old tree. I met with the arbutus nowhere else on the Reeks.

CUMMEENACAPPUL, WEST SIDE; BEENBANE.

500–510 feet.

Stellaria graminea (Linn.)
Rosa canina (Linn.)
Fraxinus excelsior (Linn.)

LAKE ACOOSE LEVEL.

500–510 feet.

Hypericum humifusum (Linn.)
Geranium Robertianum (Linn.)
Linum catharticum (Linn.)
Medicago lupulina (Linn.)
Trifolium pratense (Linn.)
T. minus (Sm.)
Fragaria vesca (Linn.)
Rubus discolor (W. and N.)
Lythrum Salicaria (Linn.)
Peplis Portula (Linn.)
Daucus Carota (Linn.)
Hippuris vulgaris (Linn.)
Hypochœris radicata (Linn.)
Crepis virens (Linn.)
Habenaria bifolia (R. Br.)—Near Lough Beg in swampy meadows.
H. chlorantha (Bab.)—With the last.
Typha latifolia (Linn.)
Eleocharis palustris (R. Br.)
Arundo Phragmites (Linn.)

SOUTH SIDE OF MOUNT BRASSEL.

500 feet.

Trichomanes radicans (Sw.)—A shepherd lad showed me where he had once gathered, and exterminated, the Killarney Fern here. I could not find it anywhere on the Reeks, but it probably still exists at their base.

DRISHANA, WEST OF GAP OF DUNLOE.

(?) 400 feet.

Filago minima (Linn.)—On stony ground near the base of the mountain by the river. This has not been recorded from Kerry before.

LXXX.—On the Equation of a Tangent Cone to a Quadric, referred to the Axes. By John C. Malet, Professor of Mathematics, Queen's College, Cork.

[Read, April 10, 1882.]

The following purely analytical method of forming this equation is I believe new:—

If the quadric

$$ax^2 + by^2 + cz^2 + 2hxy + 2gxz + 2fyz + 2lx + 2my + 2nz + d = 0$$

be referred to its axes, the equation is

$$\frac{x^2}{\alpha} + \frac{y^2}{\beta} + \frac{z^2}{\gamma} + \frac{\Delta}{\delta} = 0,$$

where

$$\Delta \equiv \begin{vmatrix} a & h & g & l \\ h & b & f & m \\ g & f & e & n \\ l & m & n & d \end{vmatrix}$$

$$\delta = c \begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix}$$

and α, β, γ are the roots of the cubic equation in λ formed by equating to 0 the discriminant of

$$ax^2 + by^2 + cz^2 + 2hxy + 2gxz + 2fyz - \frac{x^2 + y^2 + z^2}{\lambda} = 0.$$

If the quadric be a cone, Δ vanishes; and in this case being only concerned with the ratios of α, β, γ, we may write $\frac{k}{\lambda}$ for $\frac{1}{\lambda}$, where k is a constant selected at will.

Consider now the equation of the tangent cone to the quadric

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} - 1 = 0,$$

viz.—

$$SS' - P^2 = 0,$$

where

$$S' \equiv \frac{x'^2}{a^2} + \frac{y'^2}{b^2} + \frac{z'^2}{c^2} - 1,$$

and

$$P \equiv \frac{xx'}{a^2} + \frac{yy'}{b^2} + \frac{zz'}{c^2} - 1.$$

To refer this cone to the axes, equate to 0 the discriminant of

$$US' - \Pi^2 - \frac{S'(x^2 + y^2 + z^2)}{\lambda} = 0 \quad . \quad . \quad . \quad (A),$$

where

$$U \equiv \frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2},$$

$$\Pi \equiv \frac{xx'}{a^2} + \frac{yy'}{b^2} + \frac{zz'}{c^2}.$$

Differentiating (A) with respect to x, y, and z, we get the three equations

$$S'x\left(\frac{1}{a^2} - \frac{1}{\lambda}\right) - \frac{x'}{a^2}\Pi = 0,$$

$$S'y\left(\frac{1}{b^2} - \frac{1}{\lambda}\right) - \frac{y'}{b^2}\Pi = 0,$$

$$S'z\left(\frac{1}{c^2} - \frac{1}{\lambda}\right) - \frac{z'}{c^2}\Pi = 0.$$

To eliminate x, y, z from these equations, multiply respectively by

$$\frac{\lambda x'}{a^2 - \lambda}, \quad \frac{\lambda y'}{b^2 - \lambda}, \quad \text{and} \quad \frac{\lambda z'}{c^2 - \lambda};$$

add and divide by Π, when we find

$$S' + \lambda\left(\frac{x'^2}{a^2(a^2 - \lambda)} + \frac{y'^2}{b^2(b^2 - \lambda)} + \frac{z'^2}{c^2(c^2 - \lambda)}\right) = 0,$$

or

$$\frac{x'^2}{a^2 - \lambda} + \frac{y'^2}{b^2 - \lambda} + \frac{z'^2}{c^2 - \lambda} - 1 = 0.$$

But the roots of this equation are $a^2 - a_1^2$, $a^2 - a_2^2$, $a^2 - a_3^2$, where a_1, a_2, a_3 are the semiaxes major of the confocals through x', y', z'; hence the equation of the tangent cone through this point is referred to the axes,

$$\frac{x^2}{a^2 - a_1^2} + \frac{y^2}{a^2 - a_2^2} + \frac{z^2}{a^2 - a_3^2} = 0.$$

In a similar manner the equation of the tangent cone through x', y', z' to the paraboloid

$$\frac{x^2}{L} + \frac{y^2}{M} - 2z = 0,$$

when referred to the axes, is

$$\frac{x^2}{L - L_1} + \frac{y^2}{L - L_2} + \frac{z^2}{L - L_3} = 0,$$

where L_1, L_2, L_3 are the values of L for the confocal paraboloids through the point x', y', z'.

LXXXI.—Report on the Clearing of Peaty Waters. Part II.

By Gerrard A. Kinahan.

[Read, April 24, 1882].

Introductory Remarks.

In the previous Report[1] laid before the Academy it was shown, after a colorometric examination and comparison of certain streams, "that peaty colouring matter does not seem to be removed by direct oxidation." Since then I have been enabled, through the courtesy of Professor Hartley, F.R.S.E., &c., to make in his laboratory, at the Royal College of Science, analyses of samples of peaty waters in which there were facilities for oxidation, viz., aëration when falling from a great height.

In this Report it is proposed to lay before the Academy—First, the results of these analyses, and, in continuation, the analyses of some waters that receive a large amount of mineral drainage, with a short sketch of the nature of this drainage, and its effect on the peaty waters.

In the analyses the method adopted for estimating the organic carbon and nitrogen was a modification of Dittmar and Robinson's process.

The nitrogen, as nitrates and nitrites, was estimated in the following manner:—

100 cc. of the water was boiled for a short time; then, when cold, a small piece of clean platinum foil and some magnesium ribbon were put in, with a fragment of recently fused sodic chloride; after standing about 12 hours the ammonia was distilled off, and estimated by the Nessler test, and from this the nitrogen calculated.

This process is especially applicable to the estimation of very small quantities of nitrates and nitrites.

Waters becoming much Aërated.

The first waters to be described were taken from the Dargle river, at Powerscourt waterfall, in the autumn of last year (October, 1881). The day was bright, fine, and warm; but during the two previous days misty rain had fallen on the hills, so that there was a slight flood in the river, but it was not at all turbid, although it was stated by Lord Powerscourt's game-keeper, who accompanied me, to be unusually peaty.

The first sample was taken a short distance above the fall, at a point where the river flowed rapidly through a deep channel, four feet wide, in the solid rock (mica schist). From this to the foot of the fall, where the second sample was taken, the river flowed altogether over solid rock, excepting a few loose boulders and some coarse gravel lying in the channel above the top of the fall. No visible drainage of any kind enters the river between these two points, which are separated, horizontally 800 feet, and vertically 360 feet.

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[1] *Vide ante*, p. 447.

The Dargle river, above the Waterfall, drains a long mountainous glen, with to the south a couple of small branches or cooms. The mountains of the drainage area are principally composed of granite, the mica schist only coming in a short distance above the fall. In a few places in the glen there are accumulations of moraine matter, while there is a covering of peat over nearly the whole area.

There was no visible difference between the waters taken above and below the fall, either in the field or when examined and compared in the laboratory in a tube 18″ long; both showed a clear, dark-brown tint, with little suspended matter, while only a very slight brown sediment collected at the bottom when allowed to stand.[2]

The analyses of these waters (Nos. I., II. Table A, p. 603), show that the samples are practically identical. The two important constituents—organic carbon and nitrogen—being almost the same in each, the slight difference (probably due to experimental errors), being only two parts in the carbon and five in the nitrogen per 100,000,000 of the water. Nitrogen, as nitrates or nitrites, was not detected in either sample, although if any oxidation of the organic nitrogen took place during the fall, some should occur in the lower sample.

The waters next to be considered are from the Carawaystick brook, which drains the eastern peaty slopes of Lugnaquilla. Here duplicate specimens were collected in summer and winter. Although the general features of this stream have already been described in the previous Report, we may mention that, after it leaves Kelly's Lough, and has flowed for about one and a-half miles, it falls precipitately down the western side of Glenmalure into the Avonbeg, by a succession of small, often nearly perpendicular, falls, the aggregate vertical height of which, between the points, being over 700 feet (as calculated by aneroid), while horizontally they are 1600 feet apart. The channel of the fall is solid rock (granite and mica slate), with, in the clefts, &c., a little loose gravel; no side drainage appears to enter along the fall.

When the winter samples were collected, in January, 1882, there was a light mist on the hills, otherwise the day was fine and dry, but not cold: although there had been considerable rain some days previously the stream was not flooded, but rather below its average; the waters were very clear and only slightly coloured with peat, and in the 18″ tube they showed a light olive brown tint.

From the analyses as given in the Table (Nos. III. & IV.), we find that the organic carbon and nitrogen are practically the same in both samples.

In the same Table, Nos. V. and VI. give the analyses of the summer samples taken from the same points; they show the differences in the waters at these two seasons of the year; and it will be remarked that the main differences are in the organic constituents, especially the organic carbon.[3]

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[2] In peaty waters usually, on standing, a brown sediment collects at the bottom.

[3] These examples are average samples of peaty water in summer and winter.

In the next two analyses on the Table (Nos. VIII. & IX.) there is a very marked difference in the organic constituents. The waters were taken from the Ovoca river at two points—Tigroney weir and "The Black Dog"—about three miles apart, and with a fall of only 50 feet. On comparing the two, it is evident that the conditions in the intervening portion of the river are favourable for the removal of the peaty impurities. The most marked peculiarity in this part of the river is the mineral drainage (largely impregnated with sulphates of iron and alumina) that enters it, consisting of a number of small streams, which, taken together, form only a small fraction of the total volume of the main river; nevertheless, the organic carbon is reduced from 0·230 at Tigroney to 0·095 at "The Black Dog," or to less than half that previously present. The organic nitrogen suffers a reduction also, but not to the same extent: while, on the other hand, the total solids have largely increased; viz., from 4·88 at Tigroney to 9·26 at the "Black Dog," or nearly double.

In selecting streams from which to obtain aërated samples it was necessary that, between the points at which the samples were taken, there should be no alteration of circumstances likely to affect the waters, except simple unaided aëration: both the rivers from which samples were obtained (Dargle river and Carawaystick brook) are of very soft water, and, unfortunately, samples of hard water, affected only by aëration over a steep fall could not be secured; the Doonass fall, on the Shannon,[4] was visited and samples collected on both sides of the river, above and below the falls, but the results were most unsatisfactory, as there was a greater difference between the two samples from opposite banks, above the falls, than between either of these samples and those taken from below the falls. The analyses are given at the end of the Table (Nos. X.–XIII.)

In collecting the samples and in making the analyses, exceptional

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It is remarkable that in winter the rivers show very little peaty colouring. All through last winter this was the case (although there was an absence of frost and snow); but the rains towards the end of March brought down much peaty colouring: this probably may be due to the return of vegetation, which is early this spring (1882).

[4] On writing about the floods in this river to my father, who lived for some years in this neighbourhood, part of the time at Castleconnell, I received the following note:—

"In the Shannon, between Killaloe and Castleconnell, the flood waters from the counties of Tipperary and Limerick, on the S.E. and S., are 'black floods' (peaty water), especially those that flow into it between O'Brien's-bridge and Castleconnell; while the flood waters from the Clare side, to the N. and N.W., except the stream from O'Brien's-bridge bog, are 'red flood, highly charged with the red muds from the *debris* of the red basal Carboniferous shales. These different classes of flood may differently affect the water at the Falls of Doonass. If rain falls only in the counties of Tipperary and Limerick, there will be a 'black flood' over the falls; while, if the rain falls only in the county Clare it will be a 'red flood'; but if the rain is falling at both sides of the Shannon, the results will be very different. If, during such a rain-fall, you stand at the World's End weir, Castleconnell, the flood on the Limerick side will be black, and that on the Clare

precautions were taken that nothing likely to mar the results should occur. In estimating the organic constituents duplicate analyses were made in most cases, and in the weighings for the organic carbon the allowable error was taken as under three-tenths of a milligram.[5]

These results seem clearly to show that simple aëration is incapable of effecting the removal of the peaty matter. The Powerscourt samples were taken in summer, on a warm sunny day, when the waters were deeply tinted with peaty colouring matter, yet the difference between the two samples is practically nothing, although the fall is 360 feet, and the aëration exceptional. In the Glenmalure water we have samples taken on a fine day in winter, when the quantity of peaty matter was not excessive; and although in this case the fall is over 700 feet, the two samples are practically identical.

In the samples taken from the Ovoca river the results obtained are of quite an opposite character to those of the two preceding samples: here there is but a fall of 50 feet in a flow of three miles, and aëration can have but a slight effect. That the active agent is the mineral drainage, which enters the river in the intermediate portions, seems evident from the results of the experiments given in the previous Report.

The nature of these mineral waters we now propose giving a brief sketch of; but before doing so it seems desirable to give some account of the head waters of the river, more especially as all at some time have received more or less mine drainage.

The Principal Mineral Impurities of the Ovoca.

The present Ovoca river[6] is formed by the junction of the Avonmore and Avonbeg, at the *Upper* "Meeting of the Waters," and flows into the sea at Arklow, having been joined by the Daragh water, or Aughrim river, at Woodenbridge, or *Lower* "Meeting of the Waters."

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side red; the two differently-coloured waters going separately over the weir to be slightly mixed below, but the great mixing does not take place until they reach the Falls of Doonass, below which the red ferriferous waters are found to have cleared out the peaty colouring matter. The waters flowing over the falls are more often coloured with peat than otherwise. While living at Castleconnell some of the largest floods I saw on the falls were black ones. When the rain falls only to the southward of the Shannon, the 'black flood,' going over the fall, is met by a 'red flood,' coming out of the Annacotty, or Mulkear river, which neutralises and destroys the peaty colour in the water before it reaches Limerick. On account of the difference in the land on each side of the Shannon above Castleconnell the waters on each side of the river above the falls must give very different analyses."

[5] This would be as carbonic acid, so that the carbon would be $\frac{3}{11}$ of this, or about one-tenth of a milligram, which was usually on a litre of water; but in the analyses of Nos. V., VI., VII., and X.–XIII. where only 500 cc. water was used, the error was larger than this. The figures given in the Table are the means; except in those cases on which inferences are based, when the two results are stated, viz.: Nos. III. and IV., VIII. and IX.

[6] Formerly the river, as far down as Woodenbridge, was included in the Avonmore, while the river below this, in some accounts of the district written in the last century, is called the "Ovo."

The head waters of the Avonmore rise in the mountains about Glendalough (of St. Kevin) and Luggala. The Annamoe flows from Luggala; it seems to be quite free from mineral poisoning, although mining trials have been made at Lough Dan. The tributary streams which contain most mineral drainage are those from Glendalough lakes and from the vale of Glendassan, into both of which the drainage from the Luganure and Camaderry mines flow. How long these rivers have been poisoned it is hard to say; mining operations were carried on here during the last century, yet in 1832 Glendalough and Lough Dan were noted for containing the char[7] (*Salmo alpinus*), which is now confined to Lough Dan.

A sample of water taken in Glendassan, a little below where the mine drainage enters, contained in parts per 100,000, solids 7·5; of which 0·08 were lead, with a little iron, and a trace of sulphuric acid.

A sample taken at Clara bridge, after a flow of about six miles from where the last sample was taken, with a fall of about 600 feet, contained 0·04 parts lead; and one taken three miles lower down at Rathdrum mill contained 0·035 parts lead: while a fourth, taken at the Meeting of the Waters, about 13 miles from the mines, with a fall of about 900 feet, contained 0·02 parts lead. These four samples were taken on the same day, after there had been dry weather for about six weeks. The waters were very clear, with only a faint peaty tinge.

On another occasion, when the river was in slight flood, samples were taken at Clara bridge, and at the Meetings, which gave, respectively, 0·02 parts lead, and only a faint trace.

Besides this mineral drainage from Glendalough, a small quantity of mine waters enters the river between Rathdrum and the Meetings; it is, however, very insignificant, the largest stream being that at Shroughmore, flowing from Connary. The Avonbeg, which joins the Avonmore at the Meetings, has its head waters in the hills about Glenmalure, one of its principal tributaries being the already-mentioned Carawaystick brook. Some years ago lead mines were worked in Glenmalure, and the drainage from them poisoned the river so that no fish could live in it; but now, as the deleterious mineral matter has disappeared, it has become stocked with trout from the mountain streams. This river, flowing into the Ovoca river at the Meetings, supplies large quantities of peaty water.

After the junction of the two rivers, Avonmore and Avonbeg, at the Meetings, the waters flow for about a quarter of a mile to Tigroney weir, where they become thoroughly mingled. A little above this some mineral drainage enters on the left bank; but it is about a quarter of a mile lower down, in the vicinity of the Bell rock, that the principal mine waters enter, after having passed through the copper launders. On the left, or east bank, the river receives the main drain-

[7] Char are said to have again appeared in Glendalough since the mines at the west end ceased working. A salmon is said to have been seen in the Daragh water, on June 3, 1882.

age from Tigroney and Cronebane mines; and on the right bank that of Ballygahan and Ballymurtagh. Both these waters are very similar, and are treated very similarly for the extraction of the copper before entering the river.[8] They are the underground drainage of the mines, rich in sulphates of copper, iron, and alumina, with smaller quantities of other substances. The copper is extracted by running the water over metallic iron, the copper being deposited in the metallic state, and an equivalent amount of iron passes into solution, while, at the same time, a quantity of gas is evolved, which where the launders are underground is found to be highly inflammable; it seems to be hydrogen, due to the decomposition of the water, and is probably mixed with hydro-carbons; the iron exists mostly in the ferrous state, and it is not till the greater part of the copper has been deposited that it becomes deposited as ochre.[9]

A sample of the Ballygahan water, taken from the launders, was coloured a deep brown, and contained some ochre in suspension; it was strongly acid, with a metallic taste. Its constituents are given in Table B, No. VI. (p. 604). These probably all occur as sulphates; and, calculating them as such, we find as follows in grains per gallon:—

Sulphate of copper, ...	29·5.
Sulphate of iron, ...	710·7.
Sulphate of alumina, ...	712·8.
Sulphate of manganese, . . .	10·7.
Sulphate of zinc, ...	6·0.

The most interesting constituent of this water is a small trace of cobalt. Nickel, however, was not detected.

On the opposite bank, the drainage from the Tigroney and Cronebane mines, as it enters the river, is almost identical, in general composition, with that of Ballygahan; it, however, contains each constituent in less quantity.

The river, below where this drainage enters, has in general, but more markedly during warm dry weather, a somewhat turbid appearance: this is probably due to the separation and deposition of the salts of iron and alumina.

Some distance below the Ballygahan waters another mineral stream enters, on the same side, which comes down from the mines of Ballymurtagh, along the Red road. This water contains very little mineral salts, as compared with those just mentioned.

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[8] These waters appear to have attracted some attention during the last century, and are described in Rutty's *Mineral Waters of Ireland* (1757), pp. 241–245; *Philosophical Transactions*, for 1751 to 1753, by Kenroy, Henry and Bond.

[9] This ochre consists of hydrated ferric oxide and a basic sulphate (Fe_2SO_6), which separates, in the presence of cast iron, thus:

$$Fe_2O_3\,(SO_3)_3 + Fe_2 + 2H_2O = Fe_2O_3SO_3 + 2FeSO_4 + 2H_2.$$

This reaction also accounts for the hydrogen; but some of this is also produced by the couple formed by the iron and copper.

A short distance lower down, on the same bank, a small stream enters at Tinnahinch, coming from a spa, and also receiving the drainage from the waste heaps along the mine tramway. The waters were clear, but an ochreous precipitate settled out on exposure to the air; they are acid, but rather weak mineral waters.

On the opposite or left bank, some distance lower down, above or north of the village of Newbridge, a small stream—the Sulphur brook—enters: formerly this was the principal source of mineral impurity to the Ovoca river, as it received all the drainage from Upper Cronebane and most of that of Connary; but this now flows out at Tigroney, and the mineral matter in the stream is derived from the waste heaps, or attals, on the surface: considerable quantities of ochre have been deposited along its course.

Below this a small stream enters, on the right bank, at Castlemacadam; it drains the lands about the Ballymoneen mines, which some time ago were worked for sulphur and iron ores; it is now, however, free from injurious mineral impurities, and is inhabited by small fish.

This short sketch of the mineral drainage from the Ovoca mines shows that by it a large amount of salts in solution pass into the Ovoca river: this is evident both from the quantities of solids in each of the samples, and from the fact that the total solids in average samples of the river water increased from 4·88 parts, at Tigroney weir, to 9·26 parts per 100,000, or very nearly double, at the Black Dog. No true estimate, however, of the total quantity entering can be made, as such would require a series of careful measurements and analyses of each stream, at different seasons of the year. Though these mineral waters have the general effect of freeing the Ovoca river from organic impurities, the river, on the other hand, is literally poisoned by them; and no fish are to be found in it from Tigroney weir to the sea at Arklow.

Conclusions.

In this Report I hope it has been clearly shown:—

That the colorometric method of examination of peaty waters, adopted in the first part, is a fair relative, although not an absolute, method of analysis.

That the action of the air which the water of a river is subjected to is incapable of oxidizing the peaty matter, either in winter or summer, even when the natural conditions are most favourable, as when the waters are dashed into foam down a steep and great height; and that, therefore, the same will be true, *a fortiori*, in a slow and sluggish river, where only the surface is exposed to the action of the air.

That the results of the laboratory experiments given in the first part are supported by what takes place in some rivers, and that the soluble salts of alumina, iron, and manganese are capable of removing, and do actually in nature remove, the peaty colouring efficiently and rapidly.

TABLE A.—*Analysis of Peaty Waters from different localities. The constituents are stated in parts per* 100,000.

	No.		Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness equivalent to $CaCO_3$.	Total Solids.	Remarks.
Dargle R.		POWERSCOURT FALL.									*Collected Oct.* 1, 1881.
	I.	Above falls, . . .	0·946	0·072	0·001	0·000	0·073	0·84	1·27	4·20	Clear, but deeply coloured with peaty matter.
	II.	Below falls, . . .	0·944	0·077	0·001	0·000	0·078	0·88	1·27	4·40	
Carrawaystick River.		GLENMALURE FALLS. *Winter.*									*Collected Jan.*, 1882.
	III.	Above falls, . . .	0·284 0·286	0·022 0·025	0·000	0·004	0·026 0·029	1·50	0·95	3·26	Slightly coloured with peaty matter, clear.
	IV.	Below falls, . . .	0·284 0·289	0·021 0·025	0·000	0·004	0·025 0·029	1·60	0·95	3·34	
		Summer.									*Collected Aug.* 15, 1881.
	V.	Above falls, . . .	1·06	0·054	trace	0·000	0·054	1·30	0·95	—	Deeply coloured with peaty matter.
	VI.	Below falls . . .	1·17	0·053	trace	0·000	0·053	1·40	0·95	—	
	VII.	Kelly's Lough, . .	0·68	0·054	trace	0·000	0·054	1·20	0·62	—	Rather peaty.
Ovoca.											*Collected Jan.* 16, 1882.
	VIII.	Tigroney Weir, . .	0·231 0·229	0·026 0·028	trace	0·011	0·037 0·039	1·80	1·27	4·88	Slightly peaty.
	IX.	Black Dog, ...	0·098 0·093	0·019 0·019	trace	0·008	0·027	2·30	2·60	9·26	Colourless, trace Fe.
Shannon.		DOONASS FALLS.									*Col. July* 16 & 18, 1881.
	X.	Right bank above, .	1·036	0·053	0·004	trace	0·057	1·75	14·44	—	Slightly tinted with peaty colouring matter, and suspended matter.
	XI.	Left bank above, . .	0·818	0·040	0·002	trace	0·042	1·70	14·44	—	
	XII.	Right bank below, .	1·063	0·049	0·002	trace	0·050	1·87	14·75	—	
	XIII.	Left bank below, . .	1·090	0·045	0·001	trace	0·046	1·87	14·44	—	

EXPLANATION OF THE TABLE.—Samples Nos. I. and II. in the Table show the effects of aëration on peaty water in Summer, while Nos. III. and IV. show the same in Winter. Nos. III., IV., V. and VI. are a series of comparative analyses of the same stream in Winter and Summer. No. VII. the analysis in Summer of the reservoir from which one of the tributaries of this stream springs, the drainage being mainly underground. Nos. VIII. and IX. are samples of water from a river receiving a large accession of mineral impurity, and with little aëration. Nos. X.-XIII. are analyses of samples from opposite banks of a large river above and below the falls.

TABLE B.—*Analyses showing chief Inorganic Impurities of the Ovoca River Basin. Results stated in parts per* 100,000.

AVONMORE.

No.	Where obtained.	Chief impurities determined.	Present, but not quantitatively estimated.	Traces detected.	Remarks.
I.	Glendassan,	Lead, . . 0·08 Total solids,. 7·5	— —	Fe, As H_2SO_4	Turbid, and with much suspended matter, neutral.
II.	Clara Bridge,	Lead, . . 0·04 Total solids,. 4·1 Inorganic solids, 3·1 Chlorine,. . 1·4	— — — —	As H_2SO_4 — —	Clear, but slightly peaty.
III.	Rathdrum Mill,	Lead, . . 0·035 Solids, . . 3·9 Chlorine, . 1·6	— — —	— — —	Slightly peaty.
IV.	Meeting of the Waters,	Lead, . . 0·02	—	—	Clear, and slightly peaty.

SMALL TRIBUTARIES OF THE OVOCA.

No.	Where obtained.	Chief impurities determined.	Present, but not quantitatively estimated.	Traces detected.	Remarks.
V.	Tigroney (launders),	Iron, . . 163·0 Alumina, . 197·5	Cu, Mn Mg, H_2SO_4	As, Pb Zn	Brown, with ochre in suspension, acid.
VI.	Ballygahan (launders),	Iron, . . . 199·0 Alumina, . 214·0 Copper, . . 7·5 Manganese, 3·9 Zinc, . . . 2·4	Mg H_2SO_4 — — —	Pb As Co Ca —	Brown, with ochre in suspension, acid.
VII.	"Red Road" Stream,	Ferric Oxide, Alumina, 3·8 Copper, . . 0·05	Mg H_2SO_2	— —	Colourless, with ochre in suspension, slightly acid.
VIII.	Tinnahinch Stream,	Iron, . . . Alumina, . 4·8 Copper, . . 0·02 Solids, . . 22·5	Mg H_2SO_4	Zn Ca	Colourless, brown sediment, slightly acid.
IX.	Sulphur Brook,	Solids, . . 12·8	Mg	Fe_2O_3, Zn Al_2O_3 H_2SO_4	Colourless, with brown precipitate, faintly acid.

LXXXII.—On the Effects of the Lunar and Solar Tides in Lengthening the Duration of the Sidereal Day. By the Rev. Samuel Haughton, M.D., Fellow of Trinity College, Dublin.

[Read, November 14, 1881.]

The idea of a lengthening of the sidereal day, by means of the tidal effects of the moon and sun, was started by the late astronomer Delaunay, as a means of explaining the difference of the coefficient determining the moon's mean motion,

$$10{\cdot}2\,n^2,$$

found by Halley from ancient eclipses, and confirmed by Laplace by calculation; and the coefficient, found by Adams's correction of Laplace's calculation,

$$6{\cdot}11\,n^2.$$

Delaunay found that a lengthening of the sidereal day by one second in 100,000 years, would reconcile Halley's coefficient with Adams's correction of Laplace's coefficient; and he also made an attempt to calculate the lengthening of the day producible by the tidal influence of the moon and sun. As, however, he made his calculation on the equilibrium theory of the tides, and also assumed an inadmissible range of ocean tide, it is desirable to repeat his calculations on more correct data, which I have attempted to do in the following Paper.*

I shall consider two effects of the tidal action of the moon and sun—

1. The effect of the *Residual Tidal Current*, which is of the second order, as compared to the second.
2. The effect of the *Distortion Couple*, caused by the displacement of the tidal spheroid by friction, and accompanied by acceleration of tidal phase.

Proposition I.

It is required to find the rate of lengthening of the sidereal day, caused by the residual current produced by the tidal action of the moon (supposed to be always in the equator) upon the ocean, collected into an equatorial canal, of constant width and depth.

The ocean occupies about three-fourths of the surface of the earth, and is about two miles deep, on the average. If this quantity of water

* I believe that Mr. William Ferrel, of the U. S. A. Coast Survey, has made an attempt similar to my own; but as I have not seen it, I can only acknowledge here his possible priority.

be placed in an equatorial canal, extending ten degrees on each side, north and south of the equator, such an equatorial canal will be about ten miles in depth.

The velocity of the water produced in such a canal, by the earth's rotation and action of the moon, is

$$u = V_0 + \frac{k}{2\omega} \cos 2m, \qquad (A)$$

where V_0 = equatorial velocity of the earth's surface,

$$k = \frac{3}{2}\frac{M}{R^2}\frac{r}{R} = \frac{3}{2}\frac{M}{R^2}\frac{a}{R}\frac{r}{a} = \frac{1}{400{,}000}\frac{r}{a};$$

$$\omega = \frac{2\pi}{T};$$

m = moon's hour angle;

a = mean value of r.

If the alteration in the shape of the water caused by the moon's action be neglected, and r considered always equal to a, then equation (A) summed all round the equator will give

$$u = V_0,$$

for the periodic term will disappear, and no effect will be produced by the moon in retarding or accelerating the rotation of the earth. If, however, we take account of the altered shape of the water, we have

$$\frac{r}{a} = (1 - \epsilon \cos^2 m), \qquad (B)$$

where

$$\epsilon = \frac{c - a}{a};$$

c and a being the greater and lesser semiaxes of the tidal spheroid.

The periodic term in (A) thus becomes

$$udm = \frac{k}{2\omega}\left\{\left(1 - \frac{\epsilon}{2}\right)\cos 2m\,dm - \frac{\epsilon}{4}(1 + \cos 4m)\,dm\right\},$$

which, when summed all round the circumference, leaves a

$$\textit{Residual Current} = -\frac{k}{2\omega} \times \frac{\pi\epsilon}{2}. \qquad (C)$$

This small permanent residual tidal current acts in a direction opposed to the earth's rotation, and lengthens the sidereal day.

Let us proceed to calculate its magnitude.

We have

$$k = \frac{1}{400{,}000}, \qquad \omega = \frac{2\pi}{T},$$

where $T = 89{,}280$, the number of seconds in a lunar day.

Hence

$$\frac{k}{2\omega} = \frac{89{,}280}{4\pi \times 400{,}000} = 0{\cdot}01775 \text{ ft. per second.}$$

$$\textit{Residual Current} = -\,0{\cdot}01776\,\frac{\pi\epsilon}{2}.$$

If we suppose a circle described, with radius a, at the surface of this circle $\epsilon = 0$, and if ϵ_0 be the ellipticity of the tidal ellipse at the surface of the water, all the layers of water lying between the ellipse and circle will leave a residual tidal current depending on the values of ϵ, which range from $\epsilon = 0$ to $\epsilon = \epsilon_0$. The whole water between the circle and ellipse will therefore have a residual tidal current corresponding to $\epsilon = \frac{\epsilon_0}{2}$. The whole mass of water, taken for both sides of the ellipse, will be represented by

$$\pi w\,(ca - a^2),$$

where w denotes the width of the equatorial canal, and c the longer semiaxis of the tidal ellipse. This mass may be written—

$$m = \pi w a^2 \epsilon_0.$$

The retarding couple of the residual tidal current will therefore be—

$$\delta G = -\,0{\cdot}01776 \times \frac{\pi\epsilon_0}{4} \times \pi w a^2 \epsilon_0 \times a,$$

where G represents the couple animating the whole earth; or,

$$\delta G = -\,\frac{0{\cdot}01776\,\pi^2 \epsilon_0^2 a^3 w}{4} \qquad (D)$$

Now,

$$G = \omega I = \frac{\omega M a^2}{3{\cdot}06} = \frac{V_0 M a}{3{\cdot}06}, \qquad (E)$$

where I is the earth's moment of inertia with respect to the axis of rotation, and V_0 is the earth's velocity at the equator.

From (E), which may be written

$$GT = 2\pi I,$$

we have

$$G\delta T + T\delta G = 0.$$

Hence

$$\delta T = -\frac{T\delta G}{G}.$$

Substituting the values of δG and G, we find

$$\delta T = +\frac{0{\cdot}01776 \times 3{\cdot}06 \times \pi^2 \epsilon_0^2 a^3 w \times T}{4 V_0 M a};$$

but

$$V_0 = \frac{2\pi}{T} a,$$

$$M = \frac{4}{3}\pi a^3 \times 5{\cdot}5.$$

Hence

$$4 V_0 M a = \frac{32 \times 5{\cdot}5 \times \pi^2 a^5}{3T},$$

and

$$\delta T = +\frac{0{\cdot}01776 \times 3 \times 3{\cdot}06 \times T^2 \times \epsilon_0^2 w}{32 \times 5{\cdot}5\, a^2}\delta t,$$

or

$$|\delta T = +\frac{T^2 w}{1080\, a^2}\epsilon_0^2 \delta t. \qquad (F)$$

If we express δt in terms of the number of years requisite to produce any given diminution δT, in the length of the day, we have

$$\delta t = 365{\cdot}25 \times Tn,$$

which converts (F) into

$$\delta T = +\frac{365{\cdot}25\, T^3 w}{1080\, a^2}\epsilon_0^2 n; \qquad (F\ bis)$$

but $T = 86{,}400$ seconds = sidereal day;

$w = 20 \times 60 \times 6000 = 7{,}200{,}000$ feet;

$a = 21{,}000{,}000$.

Substituting these values, we finally obtain

$$\delta T = + 3{,}561{,}000\, \epsilon_0^2 n. \qquad (F\ ter.)$$

The range of tide for an equatorial canal, with moon in equator, is

$$c - a = \frac{k\delta}{\omega^2 a},$$

where δ is the depth of the canal.
Hence, we have

$$\epsilon_0 = \frac{c-a}{a} = \frac{k\delta}{\omega^2 a^2}. \qquad (G)$$

Substituting the proper values, we find for the equatorial canal, 10 miles in depth,

$$c - a = 1{\cdot}275 \text{ feet},$$

$$\epsilon_0 = \frac{1}{16{,}500{,}000}.$$

Substituting this value in (*F ter.*) we find

$$\delta T = + \frac{n}{76{,}130{,}000}. \qquad (H)$$

It would therefore take upwards of 76 *million years for the residual tidal current produced by the moon, in the ocean collected into an equatorial canal, to increase the length of the day by one second.*

Corollary.—As the tidal effect of the sun is one-half the tidal effect of the moon, the residual current produced by both would take upwards of 50 million years to lengthen the day by one second.

PROPOSITION II.

It is required to find the rate of lengthening of the sidereal day, caused by the displacement of the tidal spheroid by friction; under the same conditions as those stated in the last Proposition.

When there is no friction, the minor axis of the tidal spheroid points to the moon, and the major axis is at right angles to the moon's direction.

In the case of an equatorial canal, with the moon always in the equator, if f denote the coefficient of friction, supposed proportional to the relative velocity of the moving water, the velocity of the water is represented by

$$u = V_0 + \frac{k}{2\omega}\left(\cos 2m - \frac{f}{2\omega}\sin 2m\right). \qquad (I)$$

The periodic term vanishes, not when $m = 45°$, but when $m = 45° + x$; where x is found from the equation

$$\tan 2x = -\frac{f}{2\omega}.$$

The tidal spheroid is, therefore, displaced through an angle x, in a direction opposite to the earth's rotation, and the phases of the tide at all places are *accelerated*. If ϕ be the complement of x, the major axis of the tidal spheroid will form an angle ϕ with the direction of the moon, and the two caps of water lying between the ellipse and circle already described will give rise, by the action of the moon and anti-moon, to a retarding couple, which tends to lengthen the day.

The magnitude of this couple is

$$km \times \sin 2\phi \times a,$$

where m is the mass of water lying between the ellipse and circle; or,

$$\textit{Retarding couple} = \delta G = \pi w k a^3 \epsilon_0 \sin 2\phi.$$

This couple is of the first order with regard to ϵ_0, whereas the retarding couple produced by the residual tidal current was of the second order only.

Hence we have, as before,

$$\delta T = + \frac{3 \times 3{\cdot}06 \times T^2 w k \epsilon_0 \sin 2\phi}{8\pi \times 5{\cdot}5\, a^2}\, \delta t. \qquad (K)$$

Substituting $k = \frac{1}{400,000}$, and reducing, we find

$$\delta T = + \frac{T^2 w \epsilon_0 \sin 2\phi \, \delta t}{6,023,000\, a^2};$$

or,

$$\delta T = + \frac{365{\cdot}25\ T^3 w \epsilon_0 n \sin 2\phi}{6,023,000\, a^2};$$

or

$$\delta T = + 638{\cdot}57\ \epsilon_0 n \sin 2\phi. \qquad (L)$$

Comparing this with the rate of retardation caused by the residual tidal current, we find the ratio of the rates of retardation to be, after the same number of years,

$$\frac{638{\cdot}57 \sin 2\phi}{3,561,000\ \epsilon_0};$$

or

$$\frac{\sin 2\phi}{5577\ \epsilon_0};$$

or, since $$\epsilon_0 = \frac{1}{16,500,000},$$

ratio of rates of retardation = $2959 \sin 2\phi$.

With any sensible value of ϕ, this retardation will greatly exceed that caused by the residual tidal current.

Substituting for ϵ_0 its value, equation (L) becomes

$$\delta T = \frac{n \sin 2\phi}{25,839}. \qquad (L\ bis)$$

We have also, if x be the acceleration of tidal phase,

$$f = 2\omega \times \tan 2x;$$

or,

$$f = \frac{4\pi}{T} \tan 2x;$$

or

$$f = \frac{\tan 2x}{6875{\cdot}5}.$$

From this we calculate the friction corresponding to any value of x:—

Acceleration of phase x.	$2x$.	$\frac{1}{f}$	Number of years required to lengthen the day by one second. n.
5°	10°	38,993	148,800
10	20	18,890	75,548
15	30	11,190	51,668
20	40	8,194	40,291
25	50	5,769	33,731
30	60	3,970	29,836
35	70	2,502	27,497
40	80	1,212	26,238
$44\frac{1}{2}$	89	120	25,843
45	90	0	25,839

Corollary (1).—If we take account of the sun, as well as of the moon, the number of years in the last column should be reduced by one-third; so that a friction whose coefficient is $\frac{1}{38,993}$, corresponding to a tidal acceleration of phase of 5° (or 20^m), would increase the length of the day by one second in 100,000 years. This is the amount of retardation necessary to reconcile Halley's coefficient of the moon's secular increase of mean motion, derived from ancient eclipses, with the correction in Laplace's coefficient made by Professor Adams.

Corollary (2).—With an amount of friction corresponding to an acceleration of phase of 5° (or 20^m), the water at the equator should rise 812 feet above the level before a surface current could flow towards the poles.

LXXXIII.—On the Comparative effects of two Metameric Bodies on the Growth of Nicotiana longiflora.

By J. Emerson Reynolds, M.D., F.R.S., Professor of Chemistry, University of Dublin.

[Read, April 10, 1882.]

The study of the comparative action of metameric compounds on the growth of plants seems to deserve more attention than it has yet received from chemists and vegetable physiologists, and the aim of the communication I now beg to lay before the Academy is to show that well-marked differences in physiological activity can be detected with the aid of plants, even in cases of metameric bodies of comparatively simple constitution.

The bodies selected for experiment were ammonium sulphocyanate and its metamer thiocarbamide, or sulphurea. Both compounds are rich in nitrogen, and therefore capable of supplying a highly important element of plant food; they are easily soluble in water, and, consequently, admit of absorption through the roots of plants; moreover, their chemical relations have been carefully studied, and their differences of structure are known, hence they seemed to be very suitable for the class of work in which I proposed to employ them.

The sulphocyanate is a true ammonium salt of sulphocyanic acid, and its composition is represented by the formula

$$NH'_4\,CNS'.$$

The metamer of this body, or thiocarbamide, I discovered in 1869, and obtained in the following way:—

The salt was melted, and the temperature of the liquid raised to 170° C., when rearrangement of the components of the molecule took place; the mass, when cooled, extracted by water and crystallized, afforded fine crystals of thiocarbamide. This body contains the same elements as the sulphocyanate, and in the same proportions, and its molecular weight is the same; but its relations and chemical structure are very different, as it is a feeble base, and destitute of saline characters, while its reactions are represented by the structural formula—

$$CS\begin{matrix}NH_2\\NH_2\end{matrix}.$$

During the summer of 1881, I made several sets of experiments with these bodies on selected groups of plants which are known to afford special nitrogenised or sulphuretted products, when grown under normal conditions. Some of the results obtained are sufficiently definite to justify their publication, while others require repe-

tition under new conditions. In the present communication I shall confine myself to the statement of experiments made with a variety of the tobacco plant (*Nicotiana longiflora*). The seeds were obtained from Messrs. Veitch & Sons, and afforded a good crop of young plants, which were removed from the seed-bed, and potted singly in very sandy mountain loam, of rather poor quality, the aim being to give the plants no more nourishment than was absolutely necessary to ensure moderate development. When the plants were shifted into four-inch pots, they were allowed to become thoroughly established, and the experiments commenced.

Several sets of three healthy plants were picked out, and the members of each set were as nearly as possible in the same stage of development, *i. e.* they were of the same height, had an equal number of leaves, and equally strong stems. Each set was subjected to the same treatment; but it will conduce to clearness if I trace that of a single set.

The treatment pursued was the following:—

No. 1. was watered with Vartry water only, when necessary.
No. 2 was watered twice each week with a solution of 0·5 gram of pure thiocarbamide in 250 c.c. of water: at other times it was treated as No. 1.
No. 3 was watered twice each week (unless otherwise stated) with a solution of 0·5 gram of pure ammonium sulphocyanate in 250 c.c. of water.

The plants were under glass, but so placed as to get equal light, and to prevent any undue tendency to drawing up or "spindling."

The first to show any effects was No. 3 (*i. e.* that treated with the sulphocyanate); at the third treatment with the solution the growth was checked, and the plant seemed not only to stop development, but even to shrink in a curious way; the leaves began to droop, and became rather sickly in colour. The fourth application only intensified the symptoms of plant-poisoning by the sulphocyanate, hence the treatment was stopped, and the soil well washed out by percolation of pure water: after this the plant recovered somewhat, and recommenced growth; but it received another dose, which again checked development. Washing the soil was repeated, and another rest allowed. This treatment was continued for nearly three months, up to the 1st of December, when it presented a very miserable appearance, and was in the condition stated in the Table. This plant was then removed from the soil, and dried.

There is no doubt that I could have killed this plant at any time by continued doses of the sulphocyanate, for corresponding plants of other sets so treated with the salt were destroyed in a few weeks.

No 2 plant (*i. e.* that treated with the solution of thiocarbamide) soon gave evidence that it felt the effect of its dose, but the result

was very different from that observed in No. 3; the stem did not elongate much, but the leaves rapidly developed in length, breadth, and substance, and assumed a healthy deep-green hue. It was noticed, however, that the development was less satisfactory where the solution of thiocarbamide was alone used for watering, than where there was a washing of the soil with pure water between two doses; in the former case the edges of the lower leaves becoming discoloured and thin. The reason for this is not far to seek; for the thiocarbamide is known to undergo partial reconversion into sulphocyanate in aqueous solution, and more especially in presence of such decomposable bodies as are found in the soil. The check in development of the plant doubtless followed this partial reversion.

With the slight modification in the treatment just referred to, the plant developed remarkably; until, on the 1st of December, it was in the state described below.

No. 1 Plant (*i. e.* that treated with plain water) grew rapidly, and soon outstripped the others in height, but its stem and leaves were poor and thin as compared with No. 2.

The following Table contains the measurements, &c., of the plants, on the 1st of December :—

	No. 1 (Water).	No. 2 (Thiocarbamide).	No. 3 (Sulphocyanate).
Total height in inches from surface of soil, ...	31	23	12
Number of leaves, ...	15	14	13
Maximum length of leaf in inches, ...	9½	15¼	8
Maximum breadth of leaf in inches, ...	4¼	6	2½
Number of seed pods in different stages of development,	9	15	None.
Number of seed pods well developed, ...	1	11	None.

Corresponding results were obtained with the other sets of tobacco plants.

The next step would obviously be the determination of the relative proportions of nicotine derivable from the plants; but the amount of material at my disposal proved insufficient for the purpose. I hope, however, to be able to grow a considerable quantity during the ensuing summer, and to repeat the experiments.

The facts ascertained are, however, amply sufficient to prove that ammonium sulphocyanate acts as a powerful poison on these plants, notwithstanding the large proportion of ready-formed ammonia it contains, while its metamer thiocarbamide stimulates the growth of similar plants, and induces healthy development of all their parts, thus acting as a distinct plant food. Indeed if it were not that thiocarbamide tends to revert to the sulphocyanate after some time, the former might be regarded as a good organic manure for tobacco.

I must leave to the vegetable physiologist the task of determining the precise way in which nutrition is arrested by the sulphocyanate, and promoted by thiocarbamide: for the present I am content to have shown that their effects on the particular plants employed are widely different, though the bodies compared contain the same elements chemically united, in the same proportions within molecules of the same weight. The conclusion is inevitable that their strongly contrasted physiological action is due to diverse molecular structure. We thus learn—

1st—That the particular elements of which the bodies are composed exerted less influence on their physiological activity than the intra-molecular grouping of the component atoms.

2nd—That, in some instances at least, differences of physiological activity between metameric bodies can be easily detected with the aid of plants.

LXXXIV.—A New Determination of the Constant of Precession.

By J. L. E. Dreyer, Ph.D.

[Read, June 26, 1882.]

Among the various constants of Astronomy one of the most important is the Constant of Precession. It is remarkable how few determinations of the exact quantity of this constant have appeared during this century, considering the great number of investigations called forth by the progress of Astronomy. Not counting theoretical researches on the subject, such as those of Laplace, Leverrier, Lehmann, and Stockwell, which possess great interest, but cannot, as regards accuracy, compare with those deduced from observations, we have in reality only three recent determinations of the Constant of Precession, by Bessel, Struve, and Nyrén. My reasons for undertaking a new determination will be best described by giving a rapid sketch of the researches of these three astronomers.

Bessel founded his investigation[1] on about 2400 stars which occurred both in Piazzi's Catalogue and in the catalogue which he had himself deduced from Bradley's observations. As the epochs of the two catalogues are 1755 and 1800, he thus found for 1777·5 the value of the two constants commonly designated as m and n, with which the variation of the right ascension (α) and declination (δ) of a star is computed by the well-known formulæ

$$\frac{d\alpha}{dt} = m + n \tan \delta \sin \alpha,$$

$$\frac{d\delta}{dt} = n \cos \alpha,$$

and from m and n the constant of the "General Precession." The result thus found was some years after modified by applying certain corrections to Bradley's and Piazzi's Right Ascensions, which were made necessary by the better value for the Constant of Nutation which Lindenau in the mean time had produced, as also by the two Fundamental Catalogues for 1815 and 1825, deduced from the Königsberg observations. Bessel's modified result for the year 1800 is[2]

$$50''\cdot2235.$$

Otto Struve used for his determination[3] a very small number of

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[1] Fundamenta Astronomiae, p. 285, *et seq.*
[2] Astronomische Nachrichten, vol. iv. (1826).
[3] Mémoires de l'Académie de St. Pétersbourg, 1842.

stars, only 400, but these had been most carefully observed in Dorpat from 1822 to 1838, and the resulting positions could be compared with Bradley's positions for the epoch 1755. The interval between the two epochs was thus considerably longer than in the case of Bessel's investigation, and this is a great advantage, as any error in the adopted equinoxes will thus be divided by a larger quantity and become less detrimental. But it detracts greatly from the value of Struve's result, that he has used such a small number of stars. It is easy to see that, if we use a large number of stars, we have to a great extent a right to suppose them uniformly distributed over the celestial sphere, and we may then safely neglect the influence of the proper motion of the solar system in space, as this influence on the stars in a certain part of the sky will be counteracted by the influence on the region diametrically opposite. But 400 stars are of course *not* uniformly distributed, and Struve was thus obliged to take the proper motion of the sun into account. This he did in a very beautiful manner; but as the amount of the apparent motion of a star, occasioned by the motion of the sun in space, depends on the distance of the star, Struve had to adopt his father's expressions for the relative distances of stars of the various classes of magnitude, and it will be conceded by everybody that these expressions are anything but certain. They depend on two hypotheses, neither of which are very well founded, viz., the supposition of a uniform distribution in space of the stars of the galaxial system, and the supposition that the apparent brightness of stars generally depends on their distance from us. Unfortunately the influence of the adopted system of relative distances on the final result is not inconsiderable. Struve's result, which is for 1800,

$$50''\cdot2411,$$

has by degrees come into general use; but partly on account of the difference between it and Bessel's result, partly owing to the doubtful suppositions on which it to some extent depends, it must be considered very desirable to try by other means to deduce a new value for the Constant of Precession. This was done in 1869 by Dr. Nyrén of Pulkova, in a paper in the Swedish language,[4] but the value he found differed in a remarkable manner from the results of Bessel and Struve.

Nyrén adopted a new plan. Instead of using the brighter stars such as generally occur in Fundamental Catalogues, he chose the Right Ascensions of the large number of telescopic stars round the equator (between ± 15° declination) which could be found both in Weisse's Catalogue (deduced from observations made by Bessel in 1821–25) and in Schjellerup's Catalogue, founded on observations made by this astronomer in the years 1861–63. As the positions for these 5000

[4] Translated in the Bulletin de l'Acad. Imp. de St. Pétersbourg, 1870.

stars were determined with an interval of about forty years, with first-class instruments, and by eminent observers, and as Nyrén took special precautions to clear Bessel's positions of constant errors by comparisons with the Dorpat and Armagh Catalogues, the material thus prepared must be considered very promising for a good result. It was therefore very surprising that the comparison between Schjellerup's and Bessel's Right Ascensions showed a well-established difference $S - B = -0^s{\cdot}135$, which, after reducing the equinoxes of the two Catalogues respectively to Wolfers' equinoxes for 1830, and to an equinox for 1862, deduced from Greenwich and Paris observations, did not become smaller than $-0^s{\cdot}095$. This indicated a rather considerable correction to the adopted constant. Nyrén's final result was, for 1800,

$$50''{\cdot}1882.$$

The deviation of this result from Bessel's and Struve's is very much larger than the accuracy of modern observations should lead one to think possible. In my Paper on the personal errors in transit observations (these *Proceedings*, ser. II., vol. ii., p. 518) I have mentioned a fruitless attempt to find out whether either Bessel's or Schjellerup's Right Ascensions show any sign of errors depending on the magnitude of the stars, as such an error, if it existed, might explain the difference between the constants of precession found from bright and from faint stars. But although it turned out to be impossible to find directly whether the personal errors of Bessel and Schjellerup depended to any sensible extent on magnitude, there are many circumstances which must lead us to believe that this was *not* the case. Argelander has compared Bessel's Right Ascensions with those of W. Struve ("Positiones Mediæ"), and found $S - B = -0^s{\cdot}043$; but as the reduction of Struve to Wolfers' Fundamental-System is zero, while Bessel's is $-0^s{\cdot}012$, the difference between Wolfers' (*i.e.* Bessel's Fundamental Catalogue) and Bessel's zones would only appear to be $-0^s{\cdot}031$. As to Schjellerup, we possess a comparison between his catalogue and that deduced by Copeland and Börgen from their observations of stars between the equator and $-2°$ declination; and as these observers used the same standard system (Nautical Almanac), the result, C and $B - S = -0^s{\cdot}005$, leaves scarcely any doubt that Schjellerup's Right Ascensions are free from constant errors.

Nyrén's result must therefore be affected by some considerable errors in one of his equinoxes, and a later investigation by himself has, in fact, shown conclusively that the observations of the sun, made in Greenwich (and on which his equinox for 1862 chiefly depended), require a large positive correction to make them agree with the observations made at Pulkowa, Edinburgh, Cambridge, Paris, and Washington; and their fair accordance with the Paris observations of 1856–59 must be due to the chapter of accidents. But it is evident that this positive correction will do away with the greater part of the large difference between Schjellerup and Bessel, and consequently

bring Nyrén's constant very near to Struve's and Bessel's. Although Nyrén appears to have seen this himself, he has not determined the exact amount of the necessary correction to his constant.[5] A few years ago, however, Newcomb published a note, "Reduction of the Constants of Precession found by Bessel, Struve, and Nyrén, to a Common Equinox," in which he investigates the changes these three constants undergo, if the star-catalogues, from which they were originally derived, be referred to a common system of standard places, and as such he adopts his "Right Ascensions of Equatorial Fundamental Stars." The improved values thus found are—

Bessel, 50″·214,
Struve, 50 ·236,
Nyrén, 50 ·220.

That we are still far from possessing a satisfactory knowledge of the exact value of the Constant of Precession seems evident, particularly when we remember the doubtful assumptions on which Struve's value depends. I have therefore thought it would be of interest to determine a new value of this important constant.

When considering the materials available for an investigation of this kind, it must be remembered that it is highly desirable not to employ stars differing too much in brightness, nor too small a number of stars, in order that the result may be as free as possible from errors of observation depending on magnitude, or arising from irregular distribution of the stars over the heavens. I decided therefore to use telescopic stars, and, of catalogues of such, none seemed to me better suited for the purpose than Lalande's "Histoire Céleste Française," and Schjellerup's Catalogue of stars, the latter being the same as employed by Nyrén. Lalande's observations were made during the years 1789–1801, at the Observatory of the École Militaire, in zones of 2°; among 50,000 stars, of which his Histoire Céleste contains observations, there are about 3300 which also occur in Schjellerup's Catalogue; and as they are distributed in a fairly uniform manner over the equatorial belt (between ± 15° decl.) throughout the twenty-four hours of Right Ascension, and were observed most carefully with an interval of about sixty-six years, it seemed beyond doubt that they would furnish good material for the new determination of the Constant of Precession.

The Histoire Céleste contains only the unreduced observations which were not catalogued until 1847, when the British Government published the well-known catalogue which had been reduced by means of Schumacher's tables of reduction under the superintendence

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[5] Nyrén, Das Aequinoctium für 1865, p. 31 (Mém. de l'Acad. de St. Pétersbourg, 1876).

[6] Vierteljahrschrift der astronomischen Gesellschaft, xiii. pp. 107–110.

of Baily. But unfortunately Schumacher's tables depend too much on the values given by Lalande for the auxiliary quantities necessary for the reduction, which are far from exact, and Baily's Catalogue is, therefore, now of little or no use except as an index to the stars observed by Lalande. In 1868 the late Dr. von Asten published new tables of reduction, founded on a thorough discussion of Lalande's observations of such stars as also occur in Piazzi's Catalogue. From these tables it became necessary to reduce anew about 3600 Right Ascensions of about 3300 stars; but although this involved a considerable amount of work, the comparison of the Right Ascensions thus derived with those of Baily showed how absolutely necessary this new reduction was. I have to thank the Royal Irish Academy for placing at my disposal a grant which enabled me to procure the assistance of an experienced computer for this part of the work. It is scarcely necessary to mention that I have taken into account the valuable collection of corrections to Lalande's Observations which Argelander has published in vol. VII. of the Bonn Observations.

When the Mean Right Ascensions for the year 1800 of all the stars common to Lalande and Schjellerup had been computed, I proceeded to reduce them to 1865·0, the epoch of Schjellerup's Catalogue. As von Asten had used Bessel's constant for the construction of his tables, and Schjellerup had used Struve's, I thought it best to adopt the mean of the two constants, and deduce a correction to this mean as the final result of the investigation. By taking the mean of the precessions given for each star in Baily's and Schjellerup's Catalogue, I also took the secular variation of the precession into account without any trouble. I may add that I took every possible care to detect errors in Baily's and Schjellerup's precessions; and whenever Argelander's corrections to the original observations altered the place of the star for 1800 sufficiently to influence the third decimal of the precession, I recomputed the latter quantity for the epoch 1800 with Bessel's constant.

The Right Ascensions thus reduced to 1865 were next compared with Schjellerup's results. Wherever the difference Sch.–Lal. exceeded about $0^s\cdot7$, I examined the case carefully to find out whether there was a case of proper motion, or whether one of the two observers had failed by exactly one second (an error occasionally occurring in zone observations). If this latter was the case it was generally easy to detect the error by a reference to other star-catalogues, but if not, the amount of proper motion was determined in a similar way, unless indeed it could be taken from Mädler's Bradley, the Åbo Catalogue, or Argelander's list of 250 Proper Motions. As the majority of *large* proper motions are independent of the motion of the sun in space, and many adjacent stars are known to move in parallel directions, I thought it better not to trust to the large number of stars employed to do away with the effect of proper motion, but to correct for the latter wherever I could detect it.

Taking the mean of all the differences for each hour of Right Ascension, I found—

0^h	Schj.–Lal.	= +	$0^s{\cdot}099$	from	133	stars.
1		+	0 ·073	,,	72	,,
2		+	0 ·092	,,	80	,,
3		+	0 ·143	,,	142	,,
4		+	0 ·106	,,	121	,,
5		+	0 ·051	,,	108	,,
6		+	0 ·059	,,	128	,,
7		+	0 ·077	,,	112	,,
8		+	0 ·042	,,	125	,,
9		+	0 ·024	,,	135	,,
10		+	0 ·034	,,	117	,,
11		−	0 ·014	,,	132	,,
12		−	0 ·055	,,	156	,,
13		−	0 ·023	,,	115	,,
14		+	0 ·032	,,	107	,,
15		−	0 ·009	,,	137	,,
16		+	0 ·055	,,	149	,,
17		+	0 ·076	,,	145	,,
18		+	0 ·042	,,	185	,,
19		+	0 ·036	,,	176	,,
20		+	0 ·043	,,	207	,,
21		+	0 ·050	,,	174	,,
22		+	0 ·062	,,	140	,,
23		+	0 ·006	,,	169	,,

As will be seen from the number of stars within each hour, the stars are not quite as uniformly distributed as might have been wished, there being a minimum at 1^h–2^h, and a maximum at 19^h–20^h. But as these hours must rather be considered as exceptional, and as the single differences within 1^h and 2^h agree well *inter se* and with the majority of the remainder, there is no reason to give these hours less weight than the rest. It is not without interest to notice the prevalence of the plus sign around 3^h, and of the minus sign nearly diametrically opposite. This agrees well with the direction of the motion of the solar system through space.

The mean result of the 24 hours is—

$$\text{Schjellerup–Lalande} = + \ 0^s{\cdot}0459 \pm 0^s{\cdot}0061.$$

From this difference we have now to separate the quantities depending on the constant errors of the fundamental systems, *i.e.* of Piazzi's Catalogue and the Nautical Almanac. It appeared advisable to reduce these to Newcomb's above-mentioned standard system, which is probably sensibly free from systematic errors; besides, I could thus make my final result directly comparable with Newcomb's corrected values.

The correction to Piazzi is + 0ˢ·100, and that to the Nautical Almanac for 1861–63 is + 0ˢ·073: the difference becomes then—

$$\text{Schjellerup–Lalande} = + \ 0^{s}\cdot019 = + \ 0''\cdot285.$$

This quantity must now be considered as arising from an error in the adopted value of the constant m; and as the interval between the mean dates of the two series of observations was found to be exactly 66 years, we have for 1829·7 (the mean of the two epochs),

$$\Delta m = + \ 0''\cdot0043.$$

This correction has now to be added to the mean of the two values of m which were used for computing the precessions for 1800 and 1865. This is

$$m = 46''\cdot06225,$$

and consequently the new value is (for 1829·7),

$$m = 46''\cdot0666.$$

In order from this to determine the Constant of Precession for the epoch 1800, I adopted the values of the planetary precession, the difference between the lunisolar and general precessions, and of the obliquity of the ecliptic, given by the late Professor Peters in his memoir "Numerus constans Nutationis," and found for $1800 + t$:

$$\text{Lunisolar Precession} = 50''\cdot3752 - 0''\cdot0002168\,t.$$

$$\text{General Precession} = 50\ \cdot2365 + 0\ \cdot0002268\,t.$$

$$m = 46\ \cdot0581 + 0\ \cdot0002849\,t.$$

$$n = 20\ \cdot0589 - 0\ \cdot0000862\,t.$$

The new value of the Constant of Precession, 50″·2365 for 1800, is only 0″·0046 smaller than the value now in use in all the great astronomical Ephemerides, and the confirmation thus given to Struve's value is of importance, when we remember the uncertain foundation on which the latter rests. That my result is entitled to some weight cannot be doubted, as it depends on more than three thousand stars observed most carefully with an interval of 66 years. The result is also interesting as showing that the fainter stars, down to the ninth magnitude inclusive, are not distinguished by any common and rotatory proper motion, such as would reveal itself by their giving a different value for the Constant of Precession from that given by the brighter stars.

LXXXV.—Multiple Renal Arteries. By A. Macalister, M.D., F.R.S., Professor of Anatomy, University of Dublin.

[Read, June 26th, 1882.]

Irregularities of the renal arteries are the commonest varieties met with among the abdominal vessels; indeed these arteries present some form of variation in three cases out of every seven.

Leaving out of account those varieties which are associated with misplaced, or horseshoe kidneys, we may classify the many forms of anomalous renal arteries as follows:—

1. *Varieties of Numbers.*—The arteries may be—(α) diminished in number, and this under two conditions—(a), with absence of the left kidney, as in Weissman's case;[1] or (b), with the origin of both renals from a common stem arising from the front of the aorta, as in Portal's well-known instance. Very much more commonly (β) the arteries are increased in number.

Multiple renal arteries may be threefold—(a), Most commonly the additional branches spring from the aorta; (b), or they may come from other sources; or (c) there may be a co-existence of additional vessels from both sources.

Of the first class, there have been described cases of,

one, two, or three	right aortic renals associated with	one, two, three, or four	left aortic renals.

Of these twelve varieties, I have not found the variety of two right and four left, and I have seen, in addition, single instances of three right and five left, and three right and six left. The commonest form, next to the normal condition of one on each side, is two on the right and one on the left. The second commonest condition is the reverse; but among the forms with larger numbers the greatest number is more frequently seen on the left than on the right side. In all these cases one vessel arises in the position of the normal renal; a second commonly springs from the aorta much lower down, generally on the level of, or below, the inferior mesenteric; the third, when present, is a very short distance above the normal renal, very close to the supra-renal, and on the level of the superior mesenteric (this branch is not to be confounded

[1] In cases like those described by Hunter (Med. Trans. of the London Coll. of Physicians, vol. iii. 1785, p. 250), and by John Reid (Phys. Path. and Anat. Researches, p. 417), where there were *two* kidneys on the right, and *none* on the left, there were two right renal arteries, an upper and a lower, and none on the left. For other cases, see Edin. Med. Journal, July, 1879.

with the form, to be hereafter noticed, of a renal branch from the supra-renal). These multiple branches have been described by most anatomists, so I need not give references. Cases of five on the right are described by Otto and Meckel, and other multiple forms are recorded by many of the older anatomists.

2. *Varieties of Origin.*—Additional renals often spring from other sources, in the following order of frequency :—(α), The supra-renal, a very common source of an upper renal artery ; (β), the second, or (γ), the third lumbar artery ; (δ), the right hepatic ; (ϵ), the colica dextra ; (ζ), the external iliac ; (η), the internal, or (θ), the common iliac ; or (ι), from the middle sacral. Of all but the first I have seen but single instances. Parallel cases, however, are quoted by Otto, who has seen two instances of the last form where the anomalous branch went respectively to the right and to the left kidneys. Otto also records a curious and unique example, in which a branch from the right common iliac supplied the left kidney.

The most remarkable instance of this class of variety which I have noted is one which I have preserved in our University Anatomical Museum, taken from a male adult subject.

In this case, on the right side, there are three renals, two from the aorta, a normal, and an inferior, and one from the capsular artery. There is no capsular branch of the aortic renal on this side. On the left side there are six renals from the following varied sources :— three from the trunk of the abdominal aorta, a normal, an inferior, and a superior, which arises directly below the left aortic supra-renal, and sends an inferior capsular branch to that organ, and enters the superior extremity of the kidney. The normal renal bifurcates before it reaches the hilus.

A fourth renal artery springs from the front of the aorta, immediately above its bifurcation, and with its origin a little to the right of the middle line. If this origin were a quarter of an inch lower it would be comparable with Otto's otherwise singular instance above quoted. The fifth renal arises from the sacra media, about half an inch below the origin of that vessel, crosses over the left common iliac artery underlying the ureter, and entering the lower part of the hilus of the kidney. The sixth and lowest branch arises from the internal iliac artery immediately at its point of division, ascends, crosses the common iliac, and pierces into the lower part of the gland. This instance is thus remarkable as combining in itself three of the rarest forms of anomaly hitherto described.

3. Anomalies of branching of the renals are very common ; indeed, the number of branches whereby the normal renals enter the substance of the kidney is very inconstant ; three or four are the commonest numbers, but I have seen up to ten penetrating branches. I have, however, preserved no record of the relative frequency of these. Otto describes the renals in one case as branching into very many branches. The other extreme, that is, the entrance of the renal by a single branch into the glandular substance, is rarer than multiple division.

4. *Varieties of Entrance.*—The places where renal arteries enter the kidney vary. Usually—(α), all enter at the hilum; (β), one often enters at the lower end, and this in most cases comes from the aorta, but may be a branch of the normal renal, once from the lumbar; (γ), one may enter at the upper end, most commonly a branch of the supra-renal, but which may be from the aorta or normal renal. I have seen a vessel piercing into the front surface of the gland from the normal renal; and in another case a posterior branch passed under the inner edge of the gland, and entered the gland at the middle of its posterior surface.

5. *Varieties of Distribution of Branches.*—From the renal there may arise branches—(a), to the supra-renal capsule, very common if not normal; (b), to the diaphragm, once; (c), to the right crus of the diaphragm; (d), to the right colon; (e), to the pancreas, deep surface of the head; (f), to the testis, supplanting the normal spermatic; (g), to the right lobe of the liver. These anomalous branches, with single examples of which I have met, were all on the right side, which is curious, as the majority of the anomalies in Class No. 2 were sinistral.

In connexion with these anomalies, it is interesting that in one case of Oppolzer's anomaly, a floating kidney, where the organ was almost entirely surrounded with peritoneum, the vessels were normal, as in the case described by Urag (Wiener Medicinische Wochenschrift, 857, No. 42).

Multiplication of renal arteries is not surprising when we consider the arrangement of these vessels in other animals and their development. Thus for the elongated kidneys in fishes the arteries are numerous, and with a trace of metamerism in their succession. In the iguana and monitor, among lizards, they are also multiple, as also in snakes. The alligator and crocodile have three or four on each side. Most birds have four, five, or six pairs, of which the three uppermost arise from the aorta, and the two or three lowest from the ischiatic.

The mammalian kidney is the metanephros, or hinder part of the primitive excretory organ, and it originates from a rounded mass of mesoblast, from the intermediate cell mass at that region where the dorsal outgrowth from the Wolffian duct extends forward to the tissue behind and nearer the spine than the rest of the nephros. In this tissue the vessels originate *in situ* in the mesoblast, close to those which supply the abdominal wall. These vessels, which are thus close together, separate at an early period, though traces of this primitive relation persist in the extra-peritoneal anastomoses of the renal arteries, through their arteriæ adiposæ and capsular branches. We owe many of the anomalies above described to persistent accidental enlargements of some of these vessels.

LXXXVI.—MUSCULAR ANOMALIES, INCLUDING THOSE OF THE DIAPHRAGM, AND SUBDIAPHRAGMATIC REGIONS OF THE HUMAN BODY.

By J. F. KNOTT, F.R.C.S.I.

[Read, June 26, 1882.]

IN a Paper read before the Royal Irish Academy last year (*vide* these *Proceedings*, ante, page 407) I gave a short description of the leading Abnormalities in Human Myology which had come under my notice during a dissecting-room experience of four winters. This was fairly complete, so far as the muscles of the head, neck, and upper extremities are concerned, but included only a few of those of the trunk and lower limbs. Some of my scattered notes were mislaid at that time, and I was obliged to postpone their publication. Accordingly, I take the present opportunity of laying before the Academy the results of my observations on the muscular variations occurring in the infra-diaphragmatic segment of the human body, during an anatomical experience of five winter sessions.

Diaphragm (*phren, septum transversum, midriff*).—This muscle I have examined, with a special view to the detection of anomalies, in thirty-six cases. Besides the variations observed in these more special instances, I made notes, from time to time, of peculiarities which were casually observed, or to which my attention was called by the dissector. Special care was given to the examination of the aortic opening in the cases tabulated.

Crura. (*Appendices* of Haller, *Capita* of Albinus, *Processus* of Santorini).—The crus of either side is divided by Professor W. Krause into three parts: *crus internum* (*s. mediale*), *crus medium*, and *crus externum*. Of these, the first is attached to the bodies of the third and fourth vertebræ, and the intervertebral disc between; the middle crus arises by a small and pointed process from the front of the second vertebra, while the lateral crus, shorter and broader, arises from the anterior and outer aspects of the body and front of the transverse process of the first lumbar vertebra. Through the interval between the crus internum and crus medium pass the splanchnic nerves; lying on the outer side of which is, on the right side, the major azygos vein; on the left side, the minor. Between the middle and external crura passes the sympathetic chain on either side. The tendinous margin of the external crus forms the ligamentum arcuatum internum.

This I regard as much the best description of the arrangement and attachments of the crura. Variations in the course of the veins and nerves are, however, often met with. The hiatus aorticus not unfrequently transmits the n. splanchnicus major; sometimes both this nerve and the azygos vein (major or minor). The minor splanchnic sometimes passes through a slit in the crus internum, thus subdivid-

ing the latter into two pillars. These nerves sometimes pierce the crus medium. The v. azygos or hemiazygos may pass through the interval between the middle and external crura on the corresponding side, and either—hardly ever both—may pass through the aortic opening.

The hiatus aorticus transmitted the major splanchnic nerve in three instances; the corresponding nerve of the right side passed through the same opening in one case, while that of the left side did so in two of the thirty-six bodies. The n. splanchnicus minor of the right side pierced the crus internum in one instance. The v. azygos major passed through the aortic orifice in two of the bodies. The hemiazygos vein passed through the interval between the middle and external crura in the same subjects.

The occurrence of erratic muscular slips was noted in several of these specimens. In two cases a well-defined muscular bundle of an inch in breadth arose from the back of the sheath of the rectus abdominis, close to the xiphoid appendix. A narrow bundle of muscular fibres, stretching antero-posteriorly on the left leaflet of the cordiform tendon, was present in one case, and I have met with the same anomaly in two other instances. A muscular band, passing from the under surface of the tendon in front and to the left of the oesophageal orifice, and adherent to the upper surface of the liver at its other extremity, forming a *m. hepatico-diaphragmaticus*, was present in one of the bodies. A distinct muscular band, passing in front of the aortic orifice, was present in five cases. The other variations noted were chiefly of the extent of the costal attachments.

Obliquus abdominis externus.—The variations of this muscle I have also tabulated in thirty-six cases, besides noting other anomalies which came under my notice. The digitations of origin have been found by me, as by most other observers, to vary usually from six to nine, but in one instance no less than ten were enumerated, the eight lower ribs giving attachment, and the seventh and eight ribs having each two digitations. In two cases the twelfth rib did not give origin to any of the muscular fibres, and this variety I have also noted in five other instances (not included in the number specially examined).

Some of the fibres were twice found continuous with those of the serratus anticus magnus; in both cases these fibres were connected with the ninth rib. The posterior fibres, which, descending less obliquely than the others, pass to the iliac crest, present considerable variations in the extent of the osseous tract to which they are attached on the ilium. This I have found to vary from one-third to two-thirds of the length of the crest. In one instance (and in four other cases noted from time to time) the iliac origin of the latissimus dorsi came into absolute contact with the posterior edge of the oblique muscle at its attachment to the bone, so that the triangle of Petit did not exist. This was found in all the cases in very muscular subjects. The degree of adhesion of the aponeurosis to the *linea semilunaris Spigelii* I have found to vary very considerably: in one case it could

be separated with the greatest ease, not presenting any intimate adhesion at all; in two other cases the connexion was so slight that the aponeurosis could be satisfactorily separated till the *linea alba* was reached.

Camper's *intercolumnar bands* (*fibræ collaterales* of Winslow).–These fibres present very varying degrees of development, and I have, in emaciated subjects, sometimes found them so weak as to be able to afford hardly any strength to the upper angle of the ring. Complete absence has been observed by Professor Macalister: this I have not seen, and believe that it must be a very rare condition, as I have examined the ring with special care in more than two hundred subjects without observing it.

A variability of development somewhat proportionate to that of Camper's bands I have found to exist in the case of Colles's triangular ligament (*ligamentum inguinale internum* of Bourgery, *lig. Gimbernati reflexum* of Henle).

Obliquus externus abdominis minor (*s. secundus*).—One example of this muscle I have met with (not in any of the cases specially examined); arising from the ninth and tenth ribs at the junction of bone and cartilage, it passed down to its insertion into Poupart's ligament, about the junction of the middle and outer thirds. Its breadth at the upper end was about two and a-half inches; at the lower extremity about an inch only. About two inches of the latter were aponeurotic.

Rectus lateralis abdominis (Kelch).—This muscle has been described as arising from the tenth rib, about the middle of its lower border, and passing down between the external and internal oblique muscles, to its insertion into the crista ilii, also about the middle. I have twice met with a muscular band, to which this name may be applied, but it arose in each case from the eleventh rib, near its apex. The insertion was that of the muscle described by Kelch.

Obliquus abdominis internus.—This muscle I examined in the same subjects as the last. In these, as in other cases, its origin from Poupart's ligament varied considerably. In six instances it occupied fully two-thirds of the length of the latter structure; in twenty-two, about half; in the remaining eight the attachment was somewhat less. The costal attachments varied from two to five. In twenty-eight of thirty-six muscles, the muscle was inserted into three ribs; in three cases into five; in six into four; while in two examples the corresponding number of ribs gave attachment. In two cases (not included among the thirty-six already referred to) this muscle was so closely connected with the transversalis that I could not satisfactorily separate the adjacent surfaces. A tendinous inscription of about two and a-half inches in length was observed in one case to be placed opposite the apex of the tenth rib. This I have also noted in five other instances. In two cases (not of the thirty-six) I found a similar, but shorter, inscription opposite the eleventh rib. An isolated cartilaginous slip opposite the tenth costal cartilage I have met with twice, and similar

observations have been made by Professors Henle and Macalister. The *linea semicircularis Douglasii* which marks the level of the entrance of the deep epigastric artery within the sheath of the rectus abdominis is regarded by Retzius and by Hyrtl as the margin of a fold of the fascia transversalis, which descends from that level to cover the posterior surface of the bladder. With the description of these distinguished anatomists I cannot concur, and prefer to regard the semicircular border as the lower edge of the aponeurosis of the transversalis united with the posterior lamella of that of the internal oblique, where they cease, to pass behind the rectus muscle.

Transversalis abdominis.—The costal attachments of this muscle, in twenty-nine of thirty-six cases, were six in number. In four the attachment was to seven ribs; in the remaining three the number was reduced to five. Guthrie's description of the perforation of the lower part of the muscle by the spermatic chord was verified by two examples, and I have also seen two or three others. The reflected fibres described by Sir Astley Cooper as passing from the outer edge of the conjoined tendon and reaching along Poupart ligament as far as the internal ring, I have not found at all well developed in any case. Only a few scattered muscular bundles can be found in the aponeurotic process, which passes from the outer margin of the conjoined tendon, along the posterior wall of the inguinal canal.

Rectus abdominis.—The variations of this muscle chiefly affect the breadth, length, and number of tendinous inscriptions. The breadth opposite the umbilicus I have found to vary from two and a-quarter inches to three and three-quarters. I have traced some of the fibres to a sternal insertion in two instances. In one case I noticed that the upper attachment of the muscle was to the cartilage of the fourth and fifth ribs.

The number of tendinous inscriptions varies from two to five, three being the usual proportion. They were specially examined in sixty cases. Of these, two presented absence of the xiphoid inscription, those present being the umbilical and intermediate. I have also observed this in two other subjects, in one of which the deficiency was bilateral. The intermediate inscription was absent in one case, and I have noted two other instances. In one case observed (not included in the above sixty) there were five lineæ transversæ, two being infra-umbilical. In five of the sixty cases one infra-umbilical inscription was present, the degree of development varying greatly. The umbilical inscription was invariably present.

Doubling of this muscle on one side has been recorded by Otto; but this must be excessively rare. In some emaciated subjects I have sometimes found one or two segments easily separable into two or three fasciculi.

Pyramidalis abdominis.—This muscle I have carefully examined in sixty subjects, In nine of these the muscle was absent on both sides. In five subjects it was absent on one side only: in three of these the deficiency was on the left side; in two on the right. In six of the subjects the left was obviously smaller than the right, the difference

in length being from half to one inch. In one case a tendinous slip from the upper end of the fleshy fibres produced the insertion as far as the umbilicus: the tendinous segment was in this case about one-third the whole length. It occurred on the right side. In one case a tendinous inscription was found to cross the muscle about its middle; its development was bilateral, and the inscriptions on the same horizontal level. In another case, not included in the above number, I have seen a tendinous intersection on one side. The length of the muscle varies within wide limits, and, in my experience, ranges from little more than one-fourth of the distance between the pubis and umbilicus to two-thirds of that space. The breadth similarly varies from one-third of that of the pubic crest to the whole width of the latter.

The muscle is, in some cases, easily separated into two or three fasciculi; but I do not think that these deserve the name of double, triple, or quadruple pyramidales, such as have been occasionally described by anatomists, and from, I have no doubt, similar appearances.

Cremaster.—The only variation of this muscle which I have noted is an origin almost wholly continuous with the lower fibres of the transversalis abdominis.

Pubo-peritonealis (Macalister); *pubo-transversalis* (Krause).—I have in one subject found a delicate band of muscular fibres, corresponding in position to the anomalous muscle described under the above name by Professor Macalister. It arose from the ilio-pectineal line behind Gimbernat's ligament, and passed obliquely upwards towards the middle line, between the transversalis muscle and fascia, to within two inches of the umbilicus. It passed in front of the deep epigastric artery, and was inserted into the fascia transversalis.

Quadratus lumborum (*Scalenus lumborum* of Meyer).—According to C. Krause, the anterior portion of this muscle has normally an attachment to the body of the twelfth dorsal vertebræ. This observation does not accord with my experience; but this vertebral attachment did exist in eight, out of thirty specimens, in which it was specially searched for. The slip passed upwards and inwards in front of the twelfth rib, and below and nearly parallel to the eleventh intercostal nerve. In two cases (not included in the above number) I have found a slip to the eleventh dorsal vertebra, and, in three instances, slips to both eleventh and twelfth co-existed. In one subject a slip passed to the lower border of the eleventh rib.

Levator ani (*levator intestini recti; diaphragma pelvis*).—This muscle seldom presents any notable anomalies. An inferior slip of occasional occurrence is mentioned by W. Krause, passing separately backwards to the anus, sometimes above the transversus perinæi superficialis, and, in other cases, above the transversus p. profundus. I have once seen a band of fibres answering to the description in the last-named position.

Coccygeus.—This muscle, the rudimentary homologue of the *m.*

abductor caudæ anterior of the canine tribe (W. Krause), presents great varieties in the degrees of its development. Three times I have found complete absence of the muscular fibres; in one of these the deficiency was bilateral, and tendinous fibres took the direction of the normal muscular bundles.

Sacro-coccygeus posticus; extensor coccygis; levator coccygis (Morgagni).—This bundle of muscular fibres I have found four times in thirty subjects. Once it was bilateral; once the origin was from the posterior inferior iliac spine; in the other cases it arose from the posterior surface of the third and fourth bones of the sacrum. W. Krause regards it as the homologue of the *extensor caudæ lateralis* of the dog.

Sacro-coccygeus anticus; curvator coccygis (the homologue of the *m. flexor caudæ* of the dog, according to W. Krause).—This band of muscular fibres passes from the fourth and fifth bones of the sacrum, along the front of the coccyx, nearly to the tip of the latter. I found muscular fibres twice in sixteen subjects, and in several others tendinous bands occupied the corresponding position. I have also met with these fibres in several other instances, but they were always very weakly developed.

Transversus perinaei superficialis (*s. posterior*).—This muscular band, which was first figured by Tiedemann (1822), is described by Lesshaft as an anomalous muscle of comparatively rare occurrence (9 per cent.) Krause has, however, found its occurrence much more frequent, and I have myself found it six times in thirty subjects in which it was searched for. I have also met it casually in many other dissections. It was regarded by Theile (1841) as an aberrant slip of the sphincter ani externus. This muscle lies between the layers of the superficial fascia, passing from opposite the inner margin of the ascending ramus of the ischium, or beneath the tuberosity of this bone, forwards and inwards to the central tendinous point of the perinæum. The muscle more generally known as the *t. p. superficialis* has been named by Lesshaft the—

Transversus perinæi medius.—This muscle lies between the deep layer of the superficial fascia (so-called fascia of Colles) and the anterior layer of the triangular ligament. According to Lesshaft, this muscle is absent in thirty-five per cent. of the cases examined. In thirty subjects specially examined by me the muscle was eight times absent, the deficiency being bilateral in five cases. In the others the degrees of development varied greatly.

Transversus perinæi profundus (*s. anterior*). (*Guthrie's muscle; ischio-bulbosus*).—This muscle is placed farther forwards than that already named, and is separated from the anterior margin of the levator ani by the deep layer of the triangular ligament. The degree of development varies greatly, and it was completely absent three times in thirty bodies.

Gluteo-perinealis (Krause).—This band of muscular fibres, passing from the fascia over the inner margin of the gluteus maximus (oppo-

site the tuberosity of the ischium) to the central tendinous point of the perinæum, I have twice observed. It is a variety of *transversalis perinæi superficialis.*

Levator urethræ; pubo-urethralis; Wilson's muscle.—This muscle is now properly regarded as formed by the anterior fasciculus of the levator ani muscle. It is a small band (usually about 1 mm. in breadth), which arises about 1 cm. outside the margin of the symphysis pubis, and about the middle of its level, and passes downwards and backwards to the central tendinous point of the perinæum. It was absent five times in thirty subjects examined, the deficiency being bilateral in all cases.

Psoas magnus.—This muscle was examined on both sides in forty subjects. Some variations of origin were observed. In three instances some fibres took origin from the neck of the last rib; this peculiarity was symmetrical in two of the cases. Fibres of origin came from the lateral margin of the right crus of the diaphragm in one of these, and I have notes of three other cases in which the same was observed. An origin from the left crus I have once met with.

The origin from the last lumbar vertebra was deficient in five bodies. In three this occurred on both sides; in the other two it was unilateral, the deficiency being on the left side in both cases.

Psoas parvus.—This muscle was present in seven of the forty subjects. In five of these it was bilateral; in the other two on the right side only. The origin in all cases was as described in the ordinary text-books.

A case of psoas parvus having the usual origin, but inserted into the side of the cartilage between the third and fourth lumbar vertebræ, has been already published by me in these *Proceedings.*

Sartorius.—A case of insertion into the inner side of the capsule of the knee-joint has been already recorded. A well-marked separation between the spinous origin of this muscle and that from the interspinous notch I have four times noted. In three cases the chink transmitted a considerable branch from the ascending division of the external circumflex artery.

Quadriceps extensor cruris; rectus (externus) femoris.—Slight variations in the tendons of origin or insertion of this muscle are not unfrequent. In forty specimens, carefully examined, three presented direct continuity of the acetabular and spinous heads of origin. In one case, a small accessory tendinous slip came from the anterior superior spine; in two there was a division of the spinous origin of the muscle into two parts, separated by a thin layer of areolar tissue.

In one of the cases enumerated above, and in three others which I have from time to time observed, the tendon of insertion was covered in front, by the overlapping of the vasti tendons, which, with the cruræus, formed a canal, through which the former tendon passed to the patella.

Vasti muscles; *cruræus.*—The variations of these muscles were

almost entirely limited to the size and extent of femoral attachments, and presented but little interest. The vasti I have sometimes found bilaminar, and this is, I think, more frequent than is usually supposed: I have noted five cases of this arrangement in the internal, and three in the external muscle; and also met with several others of which I made no record.

The sub-cruræus was absent in three of the forty limbs examined.

Adductor longus.—This muscle was divided into two lamellæ along its whole length, in three cases of which I made notes. One of these was among the forty of which the femoral muscles were specially examined. In cases recorded by Wood and by Macalister this muscle received a slip from the pectineus, which joined the former by crossing in front of the profunda femoris artery. A muscular fasciculus passing to the inner side of the vastus internus, by crossing in front of the aponeurotic sheath, which forms the anterior wall of Hunter's canal, was found in one case.

Adductor brevis.—In a considerable proportion of the cases examined this muscle could, with considerable ease, be separated into two portions, the line of division being marked by the passage of a perforating artery. Clason (Upsala lakaroforen forhandl. 1872, VII. 599) describes the muscle as being separated in this way into two segments—a superior, somewhat transverse, adducting part, and an inferior portion, more vertical in direction, and chiefly concerned in the act of flexion.

Adductor magnus.—The only notable variety I have found in this muscle is the complete separation of the segment which goes to the inner condyle of the femur. This I have noted in three instances, of which only one occurred among the forty above referred to.

Adductor gracilis (*rectus femoris internus*).—This muscle rarely presents any considerable degree of deviation from the description usually given in our text-books. Tendinous fibres are sometimes formed about the junction of the middle with the lower third of the thigh, which blend with the fascia lata, after a very short course. This I have noticed in four instances.

Pectineus.—The portion of the fibres of this muscle which arise from the ilio-pectineal eminence occasionally form an accessory head of origin separate from the rest of the muscle. This happened once among forty specimens consecutively examined, and I have also noted its occurrence in two other instances. A few of its outer fibres I have once seen inserted into the front of the hip-joint capsule.

Gluteus maximus.—A thinner deep lamina, formed by those fibres of the muscle which arose from the great sacro-sciatic and posterior sacro-iliac ligaments, was separated from the superficial part of the muscle by a distinct layer of connective tissue. This occurred five times in forty subjects examined. In three instances the origin of the muscle reached to the second coccygeal vertebra only; in all the others there was the usual attachment to the third piece. An acces-

sory slip of origin from the lumbar aponeurosis occurred in two of these. This I have also noticed in three other instances.

Gluteus medius.—In five cases the anterior edge of this muscle adhered intimately to that of the minimus. A bond of union between the anterior edge and that of the gluteus minimus, with the fascia lata, is formed by the ligamentum suspensorium ossis femoris of Günther (ligamentum suspensorium trochanteris of Henle). When well developed, this band is about seven centimetres in breadth, and reaches from the outer lip of the iliac crest to a little below the trochanter major.

Gluteus minimus.—This muscle I have twice seen pierced by the gluteal vessels and superior gluteal nerve. In one of these the inferior segment was adherent to the pyriformis for the greater part of its length.

Gluteus accessorius.—A deep inner lamina of gluteus minimus passing with the tendon of the latter to its insertion, and separated from it by a thin layer of areolar tissue. Three specimens noted.

Gluteus quartus; scansorius; invertor femoris.—This name has been given to a differentiated anterior segment of the gluteus minimus, which stretches forwards and upwards to the anterior superior spine. The specimens of this anomalous muscle which I had noted were placed on record last year. It was met with once last winter, in which case the occurrence was symmetrical, the insertion being on one side into the trochanter major with that of gluteus minimus, and on the other partly into the trochanter, and partly to the side of the vastus externus.

Pyriformis.—This muscle varies a good deal in the degree of its development, but I have never met with a case of complete absence, such as has been described by Budge and by Macalister. I have noted two instances in which the sacral digitations were reduced to two. Both had been the subjects (on the corresponding side) of chronic rheumatic arthritis. The iliac origin (at upper border of great sacro-sciatic notch) was twice in forty cases separated by a distinct areolar layer from the sacral portion of the muscle. The superior gluteal nerve perforated the upper part of the muscle in one case. The splitting by the great sciatic nerve occurred three times in forty lower limbs; once it was bilateral.

Gemellus superior.—This muscle I have found absent in a considerable number of instances. Once I found its fibres joining the tendon of pyriformis, instead of that of obturator internus. In three cases dissected by me the muscle could easily be separated into two parts.

Gemellus inferior.—During the last winter session I noted for the first time two instances of the absence of this muscle. I have several times found the muscle easily divisible into two or even three fasciculi. Two cases have also been noted in which connecting fasciculi passed from this muscle to the adjacent margin of the quadratus femoris.

Obturator internus.—Slight variations in the field of origin of this

muscle are not infrequent, but they seldom amount to marked peculiarity. The most remarkable I have met with is an origin from the anterior surface of the great sacro-sciatic ligament, close to the lesser sciatic foramen. This I have seen three times. In one case the accessory slips formed a fleshy band of about three-quarters of an inch in width, and about a line and a-half in thickness. The others were hardly half so large. A distinct slip, arising from the inner surface of the ischium, above the level of the spine, was present in two subjects examined, and the slip was symmetrically developed in one case.

Obturator externus.—This muscle is very frequently divided into two layers by the obturator vessels and nerve. This division occurred in four of twenty cases consecutively examined; the upper smaller portion taking origin from the horizontal ramus of the pubis. In a somewhat smaller proportion of subjects a very intimate degree of adhesion of the tendon to the capsule of the hip-joint was noticeable.

Quadratus femoris.—Two cases of absence of this muscle have been already published, as mentioned under the head of gemellus inferior. I have found fibres of connexion passing from the latter muscle into the upper edge of the quadratus. In three cases an accessory bundle of muscular fibres took their origin from the tendon of the semimembranosus, and a similar variety has been noticed by Mr. Kelly of this city (quoted by Macalister). The lower border I have occasionally found very closely adherent to adductor magnus.

Semi-membranosus.—The tendon of origin was observed in three cases to consist of two completely distinct parts. In one the peculiarity was bilateral. A slip of insertion to the retinaculum ligamenti arcuati has been noticed by Macalister, and I believe it to be of pretty frequent occurrence, as I have observed it in a good number of cases. A distinct slip to the fascia of the leg, forming a *tensor fasciae suralis*, is mentioned by W. Krause. Of this I have met with one example.

Semi-tendinosus.—This muscle rarely presents any notable variety. The tendinous inscription I have in one case found to be doubled; in a large number of cases it was interrupted, but never completely absent.

Biceps flexor auris.—I have already published two cases of absence of the short head of this muscle. An accessory head arising from the upper part of the linea aspera has also been recorded, and since its publication I have met with two other specimens of three-headed biceps; the accessory head arising, in one case, from the upper part of linea aspera, and in the other from the internal condyloid ridge of the femur.

Of the variations of the tendon of insertion I have noted four examples of a slip to the outer tuberosity of the tibia. A tendinous band of three-quarters of an inch in breadth, passing to the tendo Achillis, came under my observation in one case: the subject had been a very muscular one.

Tensor fasciæ suralis.—A slip from the biceps to the fascia, over

the muscles of the calf, sometimes occurs, and has been described under this name. I have observed such a slip in two cases; in one it was bilaterally developed.

Tibialis anticus.—The origin of this muscle rarely presents any considerable variety. I have twice observed an accessory bundle of muscular fibres from the head of the fibula. The insertion is not so constant. Of thirty cases examined, two sent each a slip to the ligamentum cruciatum; in two others a slip was sent to the inner side of the head of the first metatarsal bone: one was found to send a process to the base of the first phalanx of the great toe. The slip to the ligamentum cruciatum is present, according to Professor W. Krause, in six per cent. of the cases examined.

Tibio-fascialis anticus (Wood); *tibialis anticus accessorius* (*s. profundus*); *tensor fasciae dorsalis pedis* (W. Krause).—Of this muscular slip I have met with two examples in forty cases consecutively noted. It was in each case united to the tibialis anticus at its origin, and the insertion was partly into the annular ligament and partly into the deep fascia on the dorsum of the foot.

Extensor proprius hallucis.—The only variety of this muscle which I have noted was a slip from its tendon to the innermost tendon of the extensor brevis digitorum. This I have observed in four instances.

Extensor digitorum longus.—The tendons of this muscle were specially examined in thirty cases. Two of these presented a slip to the innermost tendon of extensor brevis digitorum, which proceeded with it to the base of first phalanx of great toe. Two others sent slips to base of first phalanx of second toe. In one case a well-marked slip passed from the outermost tendon to the dorsum of the fifth metatarsal bone about its middle. Two sent slips to the base of this bone. In another case two slips were sent from the third and fourth tendons to the bases of the fourth and fifth metatarsal bones respectively.

Extensor hallucis longus accessorius (*s. minor*); *extensor primi internodii hallucis.*—This muscle is of very frequent occurrence, so that it is regarded by some observers as a normal structure. It was found by Professor Wood in nearly half the subjects which he examined, and other observers have recorded a proportional frequency of as much as eighty per cent. I have found a muscular slip, more or less completely continous at its origin with the lower part of the extensor proprius pollicis, and proceeding to the base of the first metatarsal bone—in sixteen cases of forty in which it was specially searched for. In four cases a slip having the same insertion came from the tendon of proprius pollicis, and in one from the innermost tendon of longus digitorum.

Peronæus longus.—This muscle I have found inseparably adherent to the brevis in three instances. In two cases I observed a tendinous slip to the base of the fifth metatarsal bone, to which it adhered, even below and behind the tendon of insertion of the peronæus brevis. In another case a slip passed forward to the under surface of the head of the first metatarsal bone. Expansions from the tendon to the bases of the third

and fourth metatarsal bones were also noted (one example of each). These anomalies were all furnished by a series of forty cases specially examined. Some other similar variations I have also from time to time noted, without making any record of their relative proportion.

Peronæus accessorius.—This name has been given to an accessory origin of the peronæus longus. I have met with two well-marked examples, each in the form of a muscular slip, about two and a-half inches in length, and a line and a-half in thickness, arising about the middle of the fibula between the long and short peronæi.

Peronæus brevis.—In the origin of this muscle I have noted no marked peculiarity except that of origin, as mentioned under the head of peronæus longus. In a good many cases a tendious prolongation was given to the origin of the short flexor of the little toe. A slip to the extensor tendon of the little toe was present six times in forty. In each case it arose either opposite to the external malleolus or immediately in front of it. A slip of corresponding origin was in one case united with the tendon of the fourth dorsal interosseous muscle, and in another was found to be inserted into the dorsum of the fifth metatarsal bone about its middle.

Peronæus quartus.—Of this muscle I have already recorded the occurrence of two specimens. I have since met with a third, having similar attachments to the others, but larger. In this case it presented the additional peculiarity of sending a second tendon to the outer surface of the os calcis behind the insertion of the other. An analogous structure has been described by Professor W. Krause.

Peronæus quintus.—Having a similar origin to that of the muscle last described, and joining the tendon of extensor digitorum longus for little toe. One specimen came under my notice last session.

Extensor brevis digitorum.—Twice in forty cases I found this muscle give a delicate tendon to the little toe, joining the expansion of the common extensor. In one of these the tendon to the great toe was absent, and I have noted this peculiarity in several other instances. In two cases a small slip was sent to the tendon of the fourth dorsal interosseous muscle : one to that of the third, and one to that of the first, have also been noted—a single example of each.

Indicator pedis.—An independent muscular band, arising from the dorsal surfaces of the astragalus and scaphoid bones ; and inserted into the extensor tendon for second toe. This I have twice met with.

Gastrocnemius.—Accessory fibres of origin of this muscle from the external lateral ligament of the knee-joint have been already recorded (five examples).

Gastrocnemius tertius.—This accessory third head of gastrocnemius has come twice under my notice during last session. One arose from the tendon of the biceps femoris ; the second from the inner division of the linea aspera, two inches above the knee-joint. Two other instances, each from the planum popliteum, have been already published.

Plantaris.—This muscle was absent three times in forty subjects examined. The average frequency of the deficiency is ten per cent.

according to Krause. In one case I found this muscle arise from the back of the head of the fibula. An accessory head from the ligament of Winslow I have found in a considerable proportion of cases, and one from the planum popliteum of femur has been noticed in another instance. The latter was of considerable size (about one-third that of the normal head of origin).

Plantaris minor (Krause); *popliteus superior s. minor* (Calori.)—When the accessory head of the plantaris is completely separate, these distinctive names have been applied to it.

Soleus.—The soleal lamina of the tendo Achillis I once found quite distinct down to its insertion. A bi-laminar fibular head was noted in three instances, the lower lamina being the smaller in each case.

Tensor fasciæ plantaris.—A muscular lamina of about three-quarters of an inch in breadth, arising from the linea poplitea of the tibia below the soleal attachment, and passing down, superficial to the inner annular ligament, to be inserted into the plantar fascia. Of this muscle I met with one example. In another subject a muscle of similar origin was inserted into the ligamentum lanciniatum.

Poplitæus.—In one case I found a small sesamoid bone in the tendon of the poplitaeus, and its development was bilateral. A double muscle once.

Poplitæus minor.—An accessory bundle of fibres arising from the outer tendon of the gastrocnemius. Found present on two occasions.

Flexor digitorum longus.—The astonishing irregularity of the arrangement of the tendons of this muscle, and of its connexion with other tendons, has been conclusively shown by Professor Turner; also by the tabulated observations of F. E. Schultze, Wood, &c. As my own observations closely agree with those of the distinguished anatomists whom I have named, I did not tabulate them.

Flexor digitorum longus accessorius.—One example of this muscle I found arising between the lower part of the usual flexor and the tibialis posticus, and, passing into the sole of the foot, divided into two slips, which joined the tendons of second and third toes. In another case it assumed the form of a

Flexor digiti secundi proprius.

Flexor digiti minimi accessorius.—A muscular slip arising from the under surface of the tendon of the common flexor before its division, and going to the little toe. Its tendon is pierced in the thecal sheath by the corresponding tendon of the flexor brevis digitorum.

Tibialis posticus.—This muscle I have seldom found to present variations of striking interest. The tendon of insertion I have noticed in three instances to send a well-marked slip to the inner tendon of the flexor brevis digitorum. An insertion into the cuboid bone has been described as an anomaly, but this will be found to be present in the majority of cases, if searched for with sufficient care.

Flexor hallucis longus.—The origin of this muscle I have found very constant. The slip given from the tendon of this muscle to that

of the flexor digitorum longus I have found absent in two instances. Thrice I have noted the presence of a tendinous slip to the second toe, which was pierced (within the thecal sheath) by the corresponding tendon of the flexor longus digitorum. In a considerable proportion of cases (twenty-two per cent., according to Krause) one or more slips may be traced to the tendons of the lumbricales.

Tibialis secundus (Bahnsen); *tensor capsulæ tibiotarsalis; tensor membranæ synovialis tarsi.*—This anomalous muscle I have found present in two cases only. The degree of development was very different in the two. Arising in either instance from the posterior surface of the tibia below the tibialis posticus, the insertion in one case was into the ligamentum lanciniatum; in the other, into the posterior surface of the capsule of the ankle-joint.

Accessorius ad calcaneum.—This muscular slip has an origin similar to that of the muscle last described. The insertion in one specimen which I examined was into the posterior part of inner surface of calcaneum.

Pronator pedis.—One example of this muscle has been already published. I have not met with any other.

Interossei pedis.—Of the varieties of the plantar set, I have noted the following:—Four present in one instance, the additional one arising from the outer side of the great toe, and inserted into the corresponding side of the base of its first phalanx; the first plantar having an accessory head from the second metatarsal bone, and a perforating artery passing between the two heads; the outer plantar having an accessory head from the sheath of the canal for the peronæus longus.

Of the dorsal set, I have found the fourth arising by a single head in one instance; the only other peculiarities I have seen were of size and extent of osseous attachment, of which a great variety exists.

Abductor hallucis.—In three cases I have found a small tendinous slip going to the second toe, and attached to the inner side of the base of its first phalanx. The frequency of the presence of this additional band is nine per cent., according to Krause. I once saw a large slip go to the tendon of the flexor hallucis longus, with which it became intimately blended.

Flexor digitorum brevis.—The tendon for little toe was absent three times in thirty cases, in which this muscle was specially examined. Krause makes the frequency of its absence as much as fifteen per cent., and I have myself seen it in many other cases without making special note of the proportional frequency. In one instance a kind of substitute was present, formed by a tendon coming independently from a fleshy bundle, which was segmented from the lower part of the flexor longus digitorum.

Abductor minimi digiti.—An accessory head of origin to this muscle from the base of the fifth metatarsal bone I have twice met with. The tendon of insertion may be completely separate from that of the flexor brevis minimi digiti: this I have found in a good many cases. A tendinous slip to the base of the fifth metatarsal bone

is present in about sixty per cent. of the subjects examined by me. W. Krause regards its occurrence as normal; the frequency of its absence, which varies from twenty-five to fifty per cent., being greater in the female. When this accessory slip has a distinct origin from the calcaneum, it forms an—

Abductor ossis metatarsi minimi digiti.—This muscle I have found, distinct enough to merit a separate description, three times in forty cases. I have also noted its occurrence in a good many other instances.

Flexor digitorum accessorius; quadratus plantæ. Massa carnea Jacobi Sylvii.—In four cases I have noted fibres of insertion going to the tendon of the flexor hallucis longus. In two of these, fibres were also attached to the connecting slip given by the tendon of the flexor hallucis to that of the brevis digitorum. The origin I have, in several cases, found to reach to the upper surface of the os calcis, and once I found some fibres arising from the anterior surface of tendo Achillis.

Lumbricales.—The only noteworthy peculiarity of this muscle which I have met with are the variations in number, which are not infrequent. The first (internal) muscle is that which I oftenest missed. I have noted its absence six times, but without taking any account of the relative frequency of the occurrence. I do not remember having observed absence of the third or fourth.

Adductor pollicis.—A slip to the base of the first phalanx of great toe I have twice noticed. It came, in each case, from the inner portion of the muscle (*caput obliquum*), and was of considerable size. Professor Krause describes, as a normal arrangement, the adhesion of the transversus pedis to this muscle, giving to the portion formed by the latter muscle the name of caput transversum.

Opponens hallucis.—A fleshy segment sometimes separates itself from the inner part of the adductor pollicis, and is inserted into the outer border of the os metatarsi hallucis. Some anatomists have erroneously regarded this slip as the homologue of the opponens hallucis.

Transversus pedis; transversalis pedis; transversus (s. transversalis) plantæ; adductor transversus hallucis; abducteur transverse.—The attachment of this muscle to the heads of the third and fourth metatarsal bones I have frequently found absent (five times in thirty-four cases). The whole muscle was absent in another of the number, and I have noted three other instances of its deficiency.

LXXXVII.—Report on a Journey among the New Zealand Glaciers in 1882. By Rev. W. S. Green, M.A. (With Plate XVIII.)

[Read, June 26, 1882.]

The whole of New Zealand consists of a line of upheaved stratified rocks, modified in the northern portion by recent volcanic activity, and in one or two other places showing traces of more ancient vulcanicity. The axis of elevation runs from S.W. to N. E., and is cut across into the North Island, South Island, and Stewart's Island, by Cook's and Foveaux' Straits. In the South Island the mountains attain to their greatest elevation, and for over one hundred miles the Southern Alps, as they were named by Captain Cook, raise their peaks far above the snow line, in no place for the whole of that distance descending to a col or pass free from eternal snow and ice. Immense glaciers fill the valleys, and the remains of still more gigantic glaciers are everywhere to be met with.

This chain, with its continuation north and south, seems to have been upheaved in Jurassic times, and though it has experienced many vicissitudes of upheaval and depression it has never since, according to Professor Hutton, been submerged. These mountains are then of vastly greater antiquity than their European rivals, and their long exposure to the frosts and storms of ages is abundantly evidenced by the heaps of loose splintered stones to which all except the higher peaks have been reduced.

The mountains lie close to the west coast; their western flanks possess a humid climate (the rain-fall at Hokitika being measured at 118 inches), and are clothed with forest and impenetrable scrub. The western glaciers in some places descend to within 670 feet of the sea, and the rivers are short and swift. This low descent of the glaciers and the mean line of perpetual snow being at about 5000 feet compared with 8000 in Switzerland, where also no glacier descends to within 4000 feet of the sea, is particularly instructive, when we consider that these Southern Alps are at about the same distance from the Equator as the Pyrenees and the city of Florence. To the east of the mountains the land drops suddenly to a level of about 2000 feet above the sea, and then by gentle slopes and immense flat bare plains sinks gradually to the coast. The continuity of the plains is broken by ridges of low rounded hills, which on close examination often prove to be old moraine accumulations; while many of the plains are the basins of ancient lakes, the old shores being very sharply defined. In the southern and northern portions of the South Island the arrangement of mountains and plains is considerably modified by the splitting up and bifurcation of the main axis of elevation, but flat plains extending to the very foot of the highest peaks of the main chain are most characteristic of New Zealand, and totally unlike other mountainous countries, where ranges

of foot-hills have to be ascended and upland valleys traversed before the higher ranges can be reached. In the province of Canterbury, where the mountains attain their greatest height in Mount Cook or Ao-Rangi, as it is called in the Maori tongue, these features are most distinctly observable, the Canterbury plains followed by the Mackenzie plains extending up to the very ice, and so flat that Dr. Haast said he would undertake to drive a buggy the whole way from Christchurch to the foot of the Tasman glaciers. We tried it with an express waggon and three horses, and nearly accomplished it. The country was level enough, but the boulders as we drew near to the glaciers proved a little too much for a wheeled vehicle, and our waggon ended its days by being capsized in the Tasman river.

These New Zealand rivers have been a source of much difficulty to colonial development. They are so swift and erratic in their courses that fords are dangerous and bridges difficult to construct. Once the rivers leave the mountains there is nothing to keep them to one channel, as the plains, being composed of loose boulders and sand, are easily eaten away by the swift streams swelled in summer by the melting of the snow. A river bed is therefore a broad sheet of gravel through which a number of small streams wander and change day by day—what was a main channel one day being quite a secondary stream in the lapse of a week or so. Much time was often spent in crossing one river with the delays of searching for fords; but now that railways run north and south the problem has been solved on the most important route by bridges, some nearly a mile in length. In the province of Otago rich woods extend right across the island to the east coast, giving place in many districts, however, to immense plains covered with tussock grass and spaniard or sword grass, except where the farmer has come and adorned the landscape with waving fields of wheat. Farther north the great snowy chain seems to form a complete barrier to the moisture and vegetation of the west: the plains, hills, and valleys are all bare, as if shaven, and of the one uniform brownish-yellow hue. Clumps of flax (*Phormium tenax*) and isolated cabbage trees (*Cordyline australis*) make the desolation appear more desolate. The rain-fall is but 25 inches. The air is clear, bright, and exhilarating, and when we do penetrate into the furthest recesses of the mountains, to the very brink of the glaciers, we at last come to a rank vegetation brought into existence by the rains condensed by the cold ice peaks. Acclimatization has produced wonderful results in New Zealand. On the great grassy plains, where the moa once stalked majestically, the skylark is now the commonest of birds, the sparrow threatens to become a plague, as the rabbit has done, and English weeds seem determined to establish themselves and attain to a fertility unexampled at home. Clouds of thistle-down fill the air, and sorrel usurps the ground prepared for oats and wheat. Amongst other interesting points brought out by this invasion of the vegetable kingdom, one at least is worthy of special notice—the failure of red clover, while white clover thrives amazingly. In the neighbouring

island of Tasmania red clover grows well, and it is now believed that till the humble bee is introduced to fertilize the flowers red clover will not propagate itself in New Zealand.

On the 12th of last November I sailed from Plymouth for Melbourne in the Orient steamer "Garonne," having arranged with Ulrich Kaufmann and Emil Boss, both of Grindelwald, to follow me in the next ship. Unfortunately smallpox broke out in my ship, and between a delay at the Cape and quarantine at Melbourne I was not able to reach New Zealand and join my men till February 5th. Immediately on landing I received a kind telegram from Dr. Hector, and a letter from the Minister for Railways enclosing free passes on the New Zealand railways for myself and guides during our stay in the Colony. I lost no time in reaching Christchurch, where I spent an afternoon in Dr. Haast's company, he being the great authority on the topography of the Southern Alps; and next morning we started in the train for the south. On arriving at Timaru we had a delay of three hours before the train left by a branch line for Albury, and we occupied the time in purchasing provisions for our mountain journey. As we were assured that we could get sheep right up to the snows of Mount Cook, we took with us but a small supply of meat in tins. Flour, meal, bread, and biscuits, formed the bulk of our stores.

On reaching Albury by rail we hired a waggon and horses, and on the evening of the next day we got our first view of the great snowy range. The contrast between the brown, flattened downs over which we drove and the purple, ice-seamed peaks was most striking. Next morning we were up betimes, as we did not know how long our journey might be, and our driver was unacquainted with the country beyond this point. Our road soon lost itself in the rolling downs, so we walked on in advance pioneering the way, and thus before midday we reached the last swell overlooking the Tasman river. We had now to descend about 200 feet, and again came upon the track leading up the river bed. This river bed of the Tasman, over two miles wide, is a broad sheet of coarse gravel, through which the river meanders in countless channels, between which are often dangerous quicksands. We drove along over marshy flats, on which numerous seagulls had their nests (one of the young seagulls we afterwards met high up on the glacier, winging its flight over the snowy range to the west coast), then across river channels, and then over wide tracts of gravel. Right before us, rising abruptly from the river bed, in the point where the valley forked, was the great mass of Mount Cook, its icy peak glittering like a pinnacle of frosted silver against the deep blue sky. On either side the mountains rose from the flat valley with the same abruptness, and the terminal face of the Hooker and Tasman glaciers closed in the end of the two branches into which the valley divided to the right and left of Mount Cook. This flat river bed, with the mountains rising from it abruptly, and from margins as sharply defined as the shores of a lake, is so typical of all the mountain valleys we

saw, that we may ask, What is the cause of a feature so distinctive? I believe the low level to which the glaciers descend, and the consequent short incline of the rivers, is a sufficient cause. The terminal face of the Tasman glacier is, according to Dr. Haast, only 2456 feet above the sea; while the mean of four observations, taken in as many days by myself, makes it 100 feet lower; and its river descends to the sea level by a fairly uniform incline of about 25 feet to the mile. If the river had a greater depth to descend before reaching the level country or sea level, it would erode a deep ravine-shaped bed, like those so common in the European Alps. High up on the mountain slopes, on the side of the valley opposite to where we travelled, were the most remarkable series of terrace formations I ever saw, their level being quite 500 or 600 feet above the present river, and their edges sharply defined. Dr. Haast considers that they form part of the margin of an ancient lake, which was dammed up by a glacier crossing the valley lower down during the last great glacier period.

Accepting, in part, this interpretation of the phenomena, several interesting questions follow, which we shall try to answer: What river or rivers fed this lake? Was it the Tasman? The present source of the Tasman being about 200 feet lower than the terraces, would be below the level of the ancient lake, so that it could not have been the feeder, unless the lake existed in an inter-glacier period, when the climate was milder, the ice-cap smaller than at present, and the source of the Tasman higher up the valley. Supposing it was not filled by the Tasman river, it seems to follow that, at the time of the existence of the lake, the great trunk glacier formed by the junction of the Hooker and Tasman glaciers must have filled up the centre of the valley, and extending far away down beyond the terraces, formed the dam which banked up the drainage of the hills above the terraces, and thus formed a lake similar to the Merjelen-see in Switzerland. At the same time the main drainage of the great glacier passed along at a lower level, and issued from its ice cave miles lower down, as the stream of the great Aletsch does at the present day.

That the Tasman glacier has been down the present valley at almost its present level, past the foot of the slopes on which the terraces occur, is proved by the existence of several little mounds of old terminal moraine which the river has failed to remove; and until the structure of these terraces is more closely examined it is quite possible to suppose that they may have been formed by the direct action of the glacier banking up the *debris* that fell from the mountain sides.

The heat as we journeyed up the river bed was intense; dark masses of rain-clouds blocked up the Hooker valley, while the Tasman remained clear, except for a passing shower. Along the course of the river small whirlwinds followed each other at regular intervals, making themselves visible by the cloud of fine sand which they whirled upwards to a height of from 50 to 100 feet.

At three P.M., on February 12th, we commenced to ford the Tasman, and at 6·30 we reached its further shore. Halting for the

night at Birch Hill sheep station, we started early next morning, and were camped at the foot of the Tasman glacier by mid-day.

Early on the 15th we started from the camp, taking with us some slight poles for observations on the motion of the glaciers, my photographic apparatus, our ice axes, and provisions for the day. Crossing a rude bridge which we had constructed, an hour's smart walking over grass-covered flats brought us to the terminal moraine, which rises up here in grassy knolls to a height of 200 feet, and, assuming a more recent appearance to the eastward, extends right across the valley, a distance of about two miles in a straight line. Nowhere is ice visible except near the farther shore where the river breaks forth. The truncated form of this termination of the glacier shows, I think, that it cannot be retreating very rapidly, if it is retreating at all, as the absence of any heaps of terminal moraine on the flat plains near to its face proves that the river outlet must have changed many times along the present terminal face to have so completely swept the valley of all outliers, except one small heap which has been protected by boulders of unusual dimensions. It may be stationary, but from consideration of the appearance of the terminal face, and from observations on the relations of the present lateral moraine to more ancient ones, to which I shall allude further on, I would conclude that the glacier is at present advancing; or if it is not doing so at the present moment, it has done so since its last retreat, as there is good evidence to prove that at a period not very remote the glacier was smaller than it now is.

We ascended the outer line of grass-covered moraine, and passing a little blue lake lying in a deep hollow, in which we discovered numerous small fish about four inches long, we ascended heaps of newer moraine composed of immense, loose, angular boulders, and finding our progress over it most fatiguing and slow, we turned off to the left in hopes that the lateral moraine might prove more practicable; but finding it just as bad, and no level ice being in sight, we descended to the hollow between the lateral moraine and the mountain side. Here we were entangled in almost impenetrable scrub composed of wild Irishman (*Discaria toumatoo*) and sword-grass (*Aciphylla colensoi*), which cut us cruelly. Occasionally we got a more open bit for a change, but nowhere could we feel ourselves safe from the chance of a broken leg or sprained ankle. After five hours of this sort of thing we again surmounted the lateral moraine, and, striking right across the glacier, in one hour reached the white ice. The cool air off the ice was most refreshing after toiling over the heated boulders under bright sunshine and sheltered from any wind, so we walked briskly ahead until two o'clock, when we reached a point from which we had a splendid view of the great cliffs of Mount Cook, and the grand amphitheatre of peaks which swept round from left to right. This view I consider quite equal, if not superior, to anything in Switzerland, and the glacier beneath our feet had an area half as great again as that of the Great Aletsch, the largest glacier of the European Alps. Tributary glaciers poured in with graceful curves from the mountain sides, and long lines

of moraine from thirty distinct ice-streams, which were in sight from this point, brought their tale of boulders to add to the great rampart which had given us such trouble to surmount. We scanned the great ice ridges of Mount Cook with anxious eyes; all its approaches seemed most difficult; the only point which was quite clear was, that our present camp would not do, and that in spite of the roughness of the road we must shift it up to where we now were. As it was getting well on for three p.m. we decided we could at present go no further, so, selecting a mark on the hill-sides, I set up a row of stakes across the glacier, and, having secured a photograph, we started back for camp, which we reached at eight p.m. On our way we deposited our ice axes, the stand of my camera, and some photographic plates, beneath a boulder, so as to have the less to carry on our next journey up the glacier.

At our lower camp the heat during the day was very great, the temperature being often 82° in the shade; the air was clear, with the barometer ranging from 27·30 to 27·40.; a brisk breeze occasionally blowing in sudden strong squalls from the south-west or north-west prevailed in the valley, while on the mountain ridges a steady fierce wind seemed to blow continuously from the west. The wood-hens or wekas (*Ocydromus australis*) were a source of constant amusement: they seemed to know no fear, and would come pecking and examining every article in our camp, and were always ready to bolt off with any small object left on the ground. They cared little for the stones we threw at them, and all night they kept up a constant whistling, accompanied by a kind of grunting noise. On the stream hard by we had an inexhaustible supply of blue ducks (*Hymenolaimus malacorhynchus*); there were never many to be seen at a time; but when we shot three or four on one day, a couple of brace more would occupy the same part of the stream next morning. They were not wild, so in order to save cartridges we generally pelted stones at the birds to get them together, and then tumbled two or three in the one shot.

Far more wild, though quite as numerous, were the Paradise ducks (*Casarca variegata*). These were splendid birds, in habits, mode of flight, and note, resembling geese rather than ducks; and the male, with his white head, kept such a good look-out, that various stratagems had to be adopted ere we secured one for the pot.

There were a few mosquitoes and sandflies, but the large blow-fly was the greatest source of annoyance. A coat or a blanket could never be laid on the ground for half an hour with impunity; even my mackintosh was considered a good receptacle for their eggs; but we kept them from our cold mutton and ducks with a few yards of mosquito net; and, after all, having your coat full of maggots does you no harm, so long as they do not, like the larvæ of moths, feed on the material.

We were astir at the dawn of February 17th, and, as soon as we had our packs ready, and the tents secured against all wekas and

other possible invaders during our absence, we started for the glacier. On reaching a pack which I had sent on to the foot of the moraine, we rearranged our loads, Kaufmann and Boss dividing all they had to carry into four loads, while my "swag" was quite as much as I could manage over the rough ground. My men adopted the plan of carrying each one load for an hour or so, and then, setting it down, scrambling back again for the others, thus making the whole journey twice. In this manner we arrived at the camping-ground we had chosen, near the shore of a little blue lake, where the whole drainage of the valley that forced its way beneath the boulders bubbled forth to the surface. The lake was embosomed in dense scrub, which here clothed the high moraine and the mountain sides. This scrub was composed of dwarf pines; birch, or more correctly beech (*Fagus*); veronicas, sixty species of which are indigenous to New Zealand, and shrubs of podocarpus, coprosma, dracophyllum, &c., and as we came along we could not resist eating the sweet red berries of *Podocarpus nivalis*, though at the time we did not know what ill effects might ensue. Of smaller plants, the fine white *Ranunculus lyallii* was everywhere abundant; it goes by the name of Mount Cook lily among the colonists, and we found its large succulent leaves most useful in our hats as a protection against the fierce rays of the mid-day sun. A little white violet became common from this camp upwards, and ferns nestled under the shade of every damp rock.

Keas, or Mount Cook parrots (*Nestor notabilis*), now made their appearance, and came screaming close to the tent. Kaufmann shot a couple, and soon had them picked, and in the soup-kettle, while Boss added a brace of ducks to our larder. Parrot soup proved so good, that from this day forward we were never without some in the kettle. Since sheep were introduced into New Zealand these parrots have acquired a taste for kidney fat, and perching on the poor unresisting animals, eat through their flesh, in order to obtain this delicacy. Further up the glacier these birds were so tame, that I knocked one on the head with a stick which I had in my hand. In the crops of about a dozen specimens of the kea which I examined, I found nothing but the green pips of the berries of *Podocarpus nivalis*, and the birds seemed confined to the zone where these berries were ripe.

As night closed in heavy drops of rain fell, and soon it began to blow a gale; but, ensconced in our felt sleeping-bags, we at first defied the elements, and slept well. After midnight, however, the weather became so terrible that sleep was impossible. The tent could not have been blown away, as it was made on Mr. Whymper's plan, the sides and floor being all in one; but I felt sure it must soon split; it fluttered and banged, and the torrents of rain never ceased lashing its sides. Thunder crashed round the mountain peaks, and when morning came there was no improvement. So far the tent resisted the rain, but now Kaufmann's sleeping bag was getting wet from soaking the damp through the tent wall, then a pool formed in our opossum rug, and it was no longer possible to keep dry. There was no chance of lighting a fire, so we sat in the

tent shivering till mid-day, and at three o'clock, seeing that it promised for a similar night, and all our things were wet, we determined to secure the tent and provisions as best we could, and retreat to our lower camp. The wet scrub drenched us as we pushed our way through it, but on reaching our camp we were soon into dry clothes. The weather cleared for an hour or so about sunset, allowing us to get our supper in comfort; but as it began to blow and rain as night came on, we made ourselves snug in our hammocks, and slept, in spite of the banging of the tent walls and beating of the rain. Next day was stormy, wet, and cold, the highest temperature being only 42°. After our mid-day meal we set off in our waterproofs to try and reach the Hooker glacier; but finding we should have to mount the steep slopes of the spur of Mount Cook through dripping ferns, we relinquished the attempt, and amused ourselves by running after and catching some young wekas. The old birds came from all points to remonstrate, and forming a wide circle, squealed and grunted forth their indignation, and as we returned their young ones unharmed, they were, I am sure, quite satisfied that their interference had a most important influence over our actions. It cleared a little about sunset, showing the mountains glistening with fresh-fallen snow, and then settled in again for a bad night, the wind still blowing a gale from the north-west. At midnight we were aroused by the most awful torrents of rain; there seemed to be no wind with it, and in the morning, when we awoke in bright sunshine, and looked out of the tent, we found the whole landscape, down almost to the foot of the glacier and surrounding hills, covered with a robe of freshly-fallen snow. These lower hills are of course covered with snow in winter, but it seldom lies on the flat valley for more than twenty-four hours at a time. We were much surprised at learning this from the shepherds, as for a long distance the valley may be considered to be at the same level as the termination of the glacier, and land in such proximity in Switzerland would be covered all through the winter with many feet of snow. The wind was now from the south, the sky blue, and as the snow was rapidly melting, I determined to start by myself for the camp at the Blue Lake, spread out the things to dry, and leave the men to follow when they had our lower camp dried and secure. It rained a little again at night, but next day was fine enough to continue our journey, which we did as usual, my men going over all the ground twice, and while they went back the last stage I pitched the tent, and cut twigs for our bedding, coprosma and veronica scrub being still in abundance. I shall not go into all the details of our troublesome journey; suffice it to say, that our fourth camp was pitched on the moraine abreast of the stakes I had erected on the glacier. On visiting them, however, I found them all lying prostrate, and blown to some distance from the holes in which they had stood. The sunshine and storms of the past seven days had so altered the surface of the glacier, that we had some little difficulty in finding the holes we had made. When we set the sticks up again,

and I ran my eye along them to the mountain side, I found that they were still in an almost perfect right line, showing that in that time no motion of any importance had taken place. This was, however, what might have been expected, owing to the flatness of the lower portion of the glacier, the incline being about 100 feet to the mile.

We returned to camp over piles of angular rocks alternating with gravel heaps, coming now and then upon a yawning chasm with sides of dirty ice and enclosing deep blue pools of ice water. The new moraine near the margin of the glacier overtopped a rampart of ancient moraine, showing that the glacier at a period not very remote was smaller than it is at present. Not only there, but at various other parts of our route, I made similar observations. The old moraine was consolidated by the disintegration of the rocks composing it, and afforded soil for numerous tufts of sword-grass and other smaller plants. Here for the first time we found the New Zealand Edelweis (*Gnaphalium grandiceps*), and my men seemed to take fresh heart after all their fagging work when we had our hat-bands adorned with the familiar little felt-like flowers. After a good night's rest on a bed of *Veronica hectori*, we continued our "swagging," and on the next afternoon, February 23rd, we reached our fifth and final camp.

We were now 3750 feet above the sea, having gained by a week's labour only 1450 feet of actual elevation, and Mount Cook still towered nearly 9000 feet above us. Our advance was here checked by the ice of the much-broken Ball glacier coming down from our left, and though we carried our "swags" on to its surface in hopes of camping farther up, the absence of scrub on the farther spurs of sufficient size to promise a supply of fire-wood made us retrace our steps and pitch our tent on a gravel flat, close to the mountain side in the angle formed by the Mount Cook and Tasman glaciers. Here a glacier stream provided us with water, and the vicinity of our camp was strewn with dead wood brought down by landslips and avalanches from the steep slopes above. While looking for a suitable nook for our tent, Boss came upon a little square patch of dwarf gnarled coprosma exactly the square of our tent: it grew by itself on the gravel in a snug corner, and seemed as if prepared so specially for our use that we did not wish to decline the hospitality of nature, so filling up the centre of the square with some cut bushes, we pitched our tent on it. Never was a bed more comfortable; its spring was perfect. We never sank to within less than five or six inches of the ground, and so long as the wekas contented themselves with squeaking and grunting, and not pecking upwards, we did not wish to deny them the comfortable lodging beneath us which they seemed to appreciate.

From this camp we made a long day's excursion up the main glacier, and completed our reconnaissance of the ridges of Mount Cook; and from a point on the medial moraine I took a circle of angles with a view to making my map, and secured a couple of negatives of the Hochstetter ice fall; but the light was so brilliant, there not being a cloud in the sky, that over exposure of my plates was

almost unavoidable. On this day we spent some time sounding crevasses. Into one moulin I lowered a stone with 320 feet of cord, but as the cord was found to have tangled, the observation could not be relied on. We then timed the fall of large stones, and on several occasions measured 5″ by my watch before the first crash was heard, giving a depth of 300 feet, and then as a series of bangs followed for as long again, these crevasses must at the lowest computation be 500 feet deep.

The glacier (Plate XVIII.) close to our camp, which I have named the Ball glacier, after John Ball, who may be looked upon as one of the fathers of Alpine exploration, had some points of special interest. Flowing from the S.W., it met the current of the main glacier coming from the north, and failing to stem it, was pushed aside down the valley, its lower portion thus making an acute angle with its former course. As our tent was in the angle, I had abundant opportunity for watching its great slopes of ice which stood up high above the moraine, and by observation I found the ice moved past at the rate of one foot per day. At one point the pressure had been sufficient to push down the moraine as a great wall might have been tumbled over, while immediately in front of our camp the glacier was building up the rampart by a constant dropping of angular stones. Even in the stillness of night these sounds evidence its icy life, and one night we heard a bang as of a cannon shot when some new crevasses sprang into existence.

The blocks of the moraine were all either sandstones or slates of the newer palæozoic formation, of which Mount Cook and all this range is composed, with occasional fragments of quartz, in which we kept a bright look out for gold and blocks of a kind of volcanic breccia, which, according to Professor V. Ball, who kindly examined a piece which I brought home, consists of fragments of pyroxene and felspar, the latter being much decomposed, and some free silica.

Our first attempt to scale Mount Cook by the southern arête was foiled by meeting a series of crags of the above-named slates, which owing to their rotten condition we could not climb. Our second attack ended in the face of a great sandstone cliff of the eastern spur. Our third and successful attempt was made for the greater part by snow and ice, and of the ascent I shall now give a few details. Immediately to the north of Mount Cook, Mount Tasman raises its glacier-clad peak, and from the basin between these two mountains descends, in a grand ice-fall, the Hochstetter glacier. This glacier forms one of the most splendid sights in the Southern Alps. Its chaos of *seracs* tinted with every icy hue, from beryl blue to silvery white, is of course quite inaccessible, as every moment the ice blocks topple over with loud boomings and crashes, and descend from level to level in clouds of ice dust. No speck of moraine pollutes its surface though a medial moraine appeared lower down, showing that the ice-fall is really a junction of two glaciers. To reach the basin or plateau above the Hochstetter ice-fall was now our object, so on the 1st of March we started at daybreak, with rugs for a bivouac and provisions for three days, and after crossing the Mount Cook glacier, and the Hochstetter glacier below

its ice-fall, we climbed the steep rocks of the spur from Mount Tasman, and after ten hours' work settled ourselves for the night on some stones beneath a large boulder about 3000 feet above the Tasman glacier.

Starting from our bivouac at six a. m., we reached the plateau above the Hochstetter glacier, and then by a glacier coming down between the northern arête and the arête connecting Mount Cook with Mount Tasman, which I have called the Linda glacier, we gained the last steep ice slopes of the peak, and after about five hours' step-cutting stood on the highest ridge at 6·20 p.m. The wind was N.W., the ice thawing rapidly; temperature about 40°. As my thermometer was broken I could not take the exact temperature; it may therefore have been even higher than 40°; it could not have been much lower. My aneroid read 19·35 inches, which, with correction to bring it into comparison with the standard instrument in the post office at Timaru, would be 19·05, and by comparison with the sea-level readings, furnished to me for that day by Dr. Hector, Superintendent of the Meteorological department, New Zealand, our elevation above the sea level would appear to have been between 12,300 and 12,500 feet, according as the possible corrections are adopted.

The mountain has been measured trigonometrically from twenty-two stations by Mr. G. J. Roberts of the Westland Survey Department, and his result of 12,349 feet is no doubt the true elevation. Though a heavy gale was driving dark masses of rain-clouds in eddies round the ice cornice on which we stood, we could see quite enough to satisfy ourselves that we were on the ice cap of the highest peak. We could not see the distant view; but there is no other pinnacle of the mountain that can enter into competition with the peak we climbed. A peak that seems almost as high, when looked at from the Tasman valley, only owes its chance of comparison to its being nearer the spectator. One peak alone with its little cap of ice presents itself as the *Höchste Spitze*, from any point of view from which a true estimate of the mountain can be formed. In the hour of daylight that remained we descended about 2000 feet; it then became quite dark, and as heavy showers of rain and sleet beat upon us I called a halt. Spending the nine hours of darkness standing on a ledge of rock, we resumed our descent next morning, reaching the Tasman glacier at six, and our camp at 7·30 p. m.

The vegetation in these high alpine regions was most interesting: veronicas of various species were of the larger plants the most numerous; the *Veronica macrantha* with its large white flowers was especially beautiful, and quite takes the place of the little rhododendron of Switzerland. Above the mean snow line, which is about 3000 feet lower than a similar line in the European Alps, numerous alpine plants and a few dwarfed stragglers from lower regions, flourished in suitable situations. Of these alpine plants I made a collection, noting the highest point at which I observed them growing. Mr. Armstrong, of the Botanical Gardens, Christchurch, kindly named most of these for me; the few he was doubtful about I have since shown to Sir Joseph

Hooker, and one of these being a new species of the genus *Haastia*, he has paid me the compliment of calling by my name. Speaking of it, he says: "This last is a beautiful thing, of which I hope that flowers may be found by future climbers." It grew in white velvet-like bosses on the rocks facing the north, the barometer being at 23·90 when I gathered it on the southern spur, giving an elevation on that day of 6500 feet. Above this there was no sign of vegetation, except a little lichen, which extended to the very top stone of Mount Cook. What struck me most about all this vegetation was that, with the exception of a yellow ranunculus and a little violet tinge in the flowers of veronica, all the flowers were white. The pink of the primula and the blue of the gentian, so familiar to my eyes, were altogether absent. My companions and I had worked so harmoniously together, that we did not break up our alpine camp without many pangs of regret, that our days among the glorious scenery of the Southern Alps had come to a close. Once more we had to return to the haunts of men, and I cannot conclude this Paper without expressing our appreciation of the boundless hospitality with which we were everywhere received by the hospitable people of New Zealand.

Some Alpine Plants of New Zealand, Mount Cook District, collected in February and March, 1882.

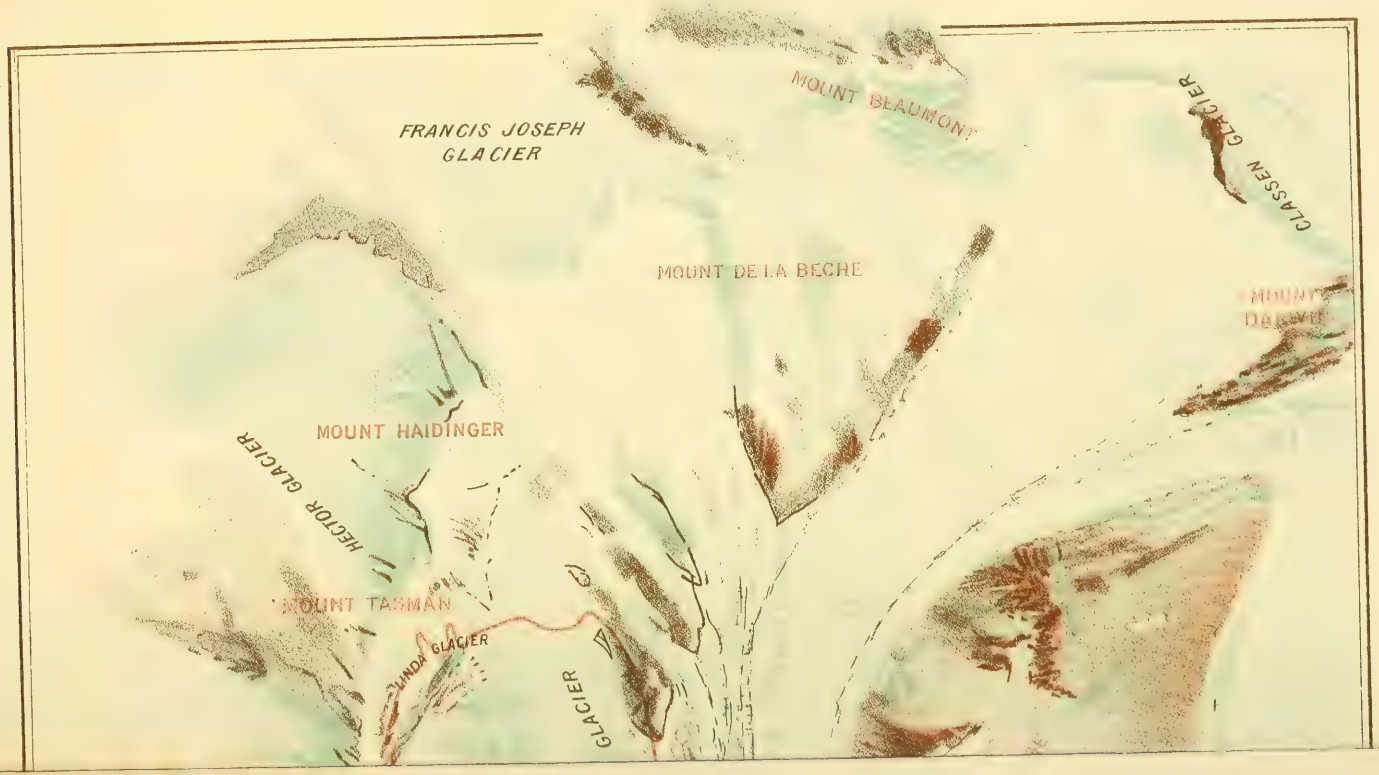
NAME OF PLANT, AND AUTHORITY.	Elevation, in feet, of Station.
Ranunculus sericophyllus (Armstrong),	6400
Ligusticum aromaticum (Hooker, fil.),	6400
Hectorella cæspitosa (Hooker, fil.),	6400
Raoulia grandiflora (Hooker, fil. and Armstrong),	6400
Haastia greenii (Hooker, fil.),	6500
Gnaphalium grandiceps (Armstrong),	3–5000
Gnaphalium bellidioides (Armstrong),	3–4000
Helophyllum colensoi (Hooker, fil.),	—
Dracophyllum rosmarinifolium (dwarf) (Armstrong),	—
Coprosma pumila (dwarf) (Armstrong),	6400
Euphrasia (?)	—
Aelmersia sessiflora,	6400

Some Meteorological Observations taken by W. S. Green *in New Zealand Alps, with Barometer reading at Sea-level worked out by* Dr. Hector, F.R.S., *at* 32° *Fahrenheit, and at* 9 A.M.

N.B.—The barometrical readings were made with an aneroid by Negreti and Zambra, having a range of from 15 to 31 inches, and which, by comparison with the standard instrument in the Post Office, Timaru (the nearest to Mount Cook), read ·3 too high. The comparison was made on February 10th.

Date.	Hour.	Place.	Weather.	Wind.	Barometer.	Shade Thermometer, F.	Bar. at Sea-level.	Observations.
Feb. 11	11 A.M.	Albury, . . .	Threatening, . .	S.	29·1	—	29·1	
,, 11	1 P.M.	Silver streams, . .	Overcast, . .	—	28·6	—	—	
,, 11	7 P.M.	Tekapo, . . .	Clear, . . .	—	27·2	52°	—	
,, 12	6 A.M.	do. . . .	do., . . .	calm	27·6	-	29·94	
,, 13	6 A.M.	Birch Hill, . . .	Clear after rain, .	N.	28·0		30·05	
,, 14	10 A.M.	1st camp, foot of Tasman Glacier, . .	Clear, . . .	N.W.	27·70	82	30·08	
,, 14	6 P.M.	do., do.,	Fine, with clouds, .	W.	27·65	64	—	
,, 15	—	do., do.,	— —	—	—	—	29·98	
,, 16	—	do., do.,	— —	—	—	—	30·06	
,, 17	6 A.M.	do., do.,	Cloudy, . . .	W.	27·40	43	29·40	
,, 18	6 A.M.	2nd camp, Blue Lake, .	Wind and rain, .	N.W.	26·75	44	29·25	
,, 19	6 A.M.	1st camp, . . .	Storm, rain, snow, .	N.W.	27·10	40	29·46	

Plate XVIII.


FRANCIS JOSEPH
GLACIER
MOUNT BEAUMONT
CLASSEN GLACIER
MOUNT DE LA BECHE
MOUNT HAIDINGER
HECTOR GLACIER
MOUNT TASMAN
LINDA GLACIER
GLACIER

FORSTER & Co LITH, DUBLIN

,,	20	6 A.M.	do.,	Clear,	S.	27·25	42	29·72	
,,	20	4 P.M.	2nd camp,	do.,	S.W.	25·10	61	—	
,,	21	5 P.M.	3rd camp,	Threatening,	S.E.	26·75	—	29·70	Thermometer broken.
,,	22	6 A.M.	do.,	Clear,	W.	27·0	—	30·12	
,,	23	6 A.M.	4th camp,	do.,	W.	26·80	—	30·20	
,,	23	6 P.M.	5th camp,	Clouds, fine,	W.	26·57	—	—	
,,	24	6 A.M.	do.,	Clouds and rain,	N.W.	26·56	—	30·30	
,,	24	6 P.M.	do.,	Clear,	W.	26·56	—	—	
,,	25	6 A.M.	do.,	do.,	S.W.	26·50	—	30·22	Ascended this day to 7000 ft. from the south arête; air still, sky blue; not a cloud visible.
,,	25	8 P.M.	do.,	do.,	calm	26·50	—	—	
,,	26	6 A.M.	do.,	do.,	light S.	26·50	—	30·23	Temperature during day about 80° in shade, seldom falling to 32° at night.
,,	26	6 P.M.	do.,	do.,	W. light	26·55	—	—	
,,	27	6 A.M.	do.,	do.,	—	26·58	—	30·18	Ascended to 8000 ft. on eastern spur: some light clouds; clear moonlight.
,,	28	6 A.M.	do.,	Overcast,	—	—	—	30·18	
Mar.	1	6 P.M.	Bivouac on Tasman spur	Fine,	S.E.	23·0	—	30·18	
,,	2	6·20 P.M.	Summit, Mt. Cook,	Clouds, rain, high wind	N.W.	19·35	about 40	30·11	Rapid thaw; ice streaming with water; temperature at sea-level 65°.
,,	3	7 P.M.	5th camp,	Thunder, rain,	N.	26·10	—	30·98	
,,	4	6 A.M.	do.,	Clouds, fine, showers,	N.W.	26·10	—	29·97	

LXXXVIII.—Computation of Tides—Results of Theory and Observation. By James Pearson, M.A., Ex-Scholar (15th Wrangler) of Trinity College, Cambridge; Vicar of Fleetwood. (With Plate XIX.)

[Read, November 13, 1882.]

The subject of Tides, upon which, from time to time, I have had the honour of addressing the Royal Irish Academy, is one of which the importance can hardly be overrated, whether we regard it in its connexion with physical science or in its reference to practical navigation. A ship, on arriving at her port of destination, requires a safe access and convenient place of discharge, and these cannot be secured unless it is ascertained that a sufficient depth of water will be found to keep her afloat, and that a suitable time has been fixed upon for her entrance into the tidal harbour. Hence the exigencies of the case demand strict attention be paid to the amount of rise and fall of tide. A rough guess is not sufficient; an error of a few inches may cause the vessel to take the ground, and so to be left high and dry twice in twenty-four hours; and this for several days, in fact until the return of spring tides supplies water enough for her draught. Now this has a double inconvenience and loss. There is the expense of delay in her discharge, which is often very considerable—wages incurred without work, and time idly squandered. If an attempt is made to lighten her by removing some of her cargo, it may be unsuccessful, and involves expenditure. More than this, the grounding of a ship of magnitude and in full load is most injurious. A severe strain takes place from the effects of which she can hardly ever be recovered; and if the ground be very hard and uneven, she may "break her back." Now these are not exaggerated dangers; and therefore whatever can be done to prevent their occurrence is a real boon to mercantile interests.

Impressed with these considerations, and having all the theoretical information on the subject which a knowledge of mathematics could supply, combined with an ardent love of what I may call an "unfrequented study," with the singular advantage of having my home within two hundred yards of a self-registering tide-guage, I have for the last twelve years practically applied myself, not only to the main problem, but also to the discrepancies involved in consequence of atmospheric disturbances, and evidence is now forthcoming to show that the success has been very remarkable. Self-praise is no recommendation, but those who have used the Admiralty Tide Tables for Liverpool during the last five years, have been prompt to testify to the improvement which has taken place in their predictions of the height of tides. The calculations now are based on a modification of Bernouilli's, or the Equilibrium Theory; and the figures employed were, in the first instance, taken from Sir John W. Lubbock's "Elementary Treatise on

the Tides." But the principle of the method is one which never occurred to either of these philosophers, nor, if known at all, has it been published by anyone else. The principle involved is this : that the configuration of land and water on the surface of the globe brings it to pass that the *direction* of the moon's motion in respect to the equator makes a very great difference in the magnitude of the tide-wave which reaches our shores. For when the moon advances from south to north declination, crossing the equator, as she sometimes does, at an angle of 28 degrees, it is seen that her line of motion approximately coincides with the general trend of the Atlantic Ocean, at the time when the earth's rotation brings that part of the globe directly beneath her, and this causes a further development of the tide-wave in the direction of Europe and North America ; whereas, when the moon declines from north declination to south, her course is diagonal to the former one, crossing the Atlantic, roughly speaking, in the direction of its *breadth*, whilst in the other case she crossed in the direction of its *length*. The like phenomena take place in connexion with the obverse action of the moon on the opposite side of the globe, when that is the agency considered. The same remarks also apply in regard to the action of the sun, only this action is much more gradual and constant. Following out the principles thus briefly enumerated, a patient attention to the actual phenomena for twelve years has enabled me to draw up tables of computation which include every possible cause which can effect or interfere with the working of the tides.

Other principles of computation, however, have found favour with the Tidal Committee of the British Association, for the details of which the Annual Reports must be consulted. In the "Harmonic Analysis of the Tides," as it is called, the various changes of level to which the sea is subject, moment by moment, in consequence of the tide-generating forces, are ascertained by the enumeration of a series of Harmonic Functions, each of which involves the time for which the computation is made, certain quantities depending on the angular velocity of the earth's rotation, the rates of relative orbital motion of the moon and sun, and certain constants. The relative merits of these rival theories (for such they are, though to a certain extent based on common fundamental physical laws) can only be tested by comparison with observation, and for this purpose no place is more eligible than Liverpool, where the equinoctial tides sometimes range as far as thirty-one feet from low-water. I am not aware, however, that this has been done.

Meantime, I desire to send to the Academy a sort of challenge-list of comparisons, taken for a semi-lunation in the month of June, 1882. The atmospheric conditions during this period were exceedingly constant, and so they very slightly affect the results. I am now engaged in forming a Table, the arguments of which are the direction and force of the wind on the one hand, and the height of the barometer on the other. By the aid of this, predictions may be made with much accuracy in unsettled weather.

Comparison of Tides from June 17 to June 29, 1882, at Fleetwood, and confirmed by Registers at Liverpool.

Date.	Calculation.	Observation.	Error.	Barometer.	Wind, &c.
1882.	ft. in.	ft. in.	in.	in.	
June 17.	26 0	25 7	− 5	29·9.	W.S.W., slight.
,, 18.	26 4	26 5	+ 1	29·6.	W., fresh.
	25 7	25 6	− 1	,,	N.N.W., ,,
,, 19.	25 9	25 10	+ 1	29·8.	,, ,,
	24 11	24 10	− 1	29·9.	,, ,,
,, 20.	25 3	25 2	− 1	,,	,, calm,
	23 10	23 11	+ 1	,,	,,
,, 21.	24 2	24 4	+ 2	29·8.	W.S.W., slight.
	22 10	23 2	+ 4	,,	,, ,,
,, 22.	23 3	23 4	+ 1	29·7.	,, ,,
	22 1	22 4	+ 3	,,	N., calm.
,, 23.	22 5	22 5	0	,,	W.S.W., ,,
	21 1	21 5	+ 4	,,	calm.
,, 24.	21 4	21 5	+ 1	29·9.	,,
	20 4	20 9	+ 5	29·8.	S., fresh, bar. falling.
,, 25.	20 7	20 11	+ 4	29·9.	,, ,,
	20 1	20 4	+ 3	30·0.	,, ,,
,, 26.	20 6	20 8	+ 2	,,	calm.
	20 10	20 10	0	,,	,,
,, 27.	21 3	21 2	− 1	30·1.	N.N.W., slight.
	21 11	22 0	+ 1	,,	,, ,,
,, 28.	22 3	22 3	0	30·2.	S.W., calm.
	23 3	23 4	+ 1	,,	N., ,,
,, 29.	23 6	23 4	− 2	,,	bar. rising. ,,
	24 10	24 8	− 2	,,	,, ,,

But, in order to submit the newly-devised method to a still more severe and crucial test, it is necessary to examine what may be called *correlative tides*, i.e. tides having nearly the same constituents: for as like causes produce like effects in nature, such tides should show the same agreement between theory and observation. This plan becomes more simple, because any one tide in any year has only one tide corresponding to it in any other year; and if there be a discordance, it must be due to a difference in atmospheric conditions, and will indicate the change of height of tide arising from this cause.

Thus, if we take the Lunar and Solar Tide which is connected with that transit of the moon, which occurs in *May*, at between 6h. and 7h., Greenwich apparent time, and compare theory with observation during the last seven years, we find as follows:—

Years.	Moon's Trans.	Moon's Par.	Moon's Dec. S. asc.	Calculation.	Observation.	Error.
	h. m.	′ ″	° ′	ft. in.	ft. in.	in.
1876.	6 31	55·27	14·17	20 9	20 3	− 6
1877.	6 33	54·16	16·53	20 2	20 2	0
1878.	6 41	54·18	5·27	21 1	21 0	− 1
1879.	6 45	55·38	8·45	21 5	21 2	− 3
1880.	6 25	58· 4	13·44	22 2	22 2	0
1881.	6 17	58·52	6·14	23 3	23 2	− 1
1882.	6 25	59·16	8·52	23 0	23 0	0

The above are favourable specimens: all others are not equally so. We shall next examine the atmospheric conditions which seem to account for the variation. Thus, if we take the Lunar and Solar Tides of *August*, which are incident to the moon's transit between 11h. and noon in the same years, with the atmospheric conditions—

Years.	Moon's Trans.	Moon's Par.	Moon's Dec. N. desc.	Calculation.	Observation.	Barometer.	Wind, &c.
1876.	11·26	60·30	17·44	28· 0	27·9	29·8.	calm.
1877.	11·50	61·19	18·27	28· 3	28·2	29·8.	N.W., slight.
1878.	11·44	60·44	9·41	28· 9	28·7	29·7.	S., slight.
1879.	11·14	57·36	15·27	26· 6	26·5	29·6.	N.W., fresh.
1880.	11·49	55· 6	14·17	25·10	25·9	29·8.	W., slight.
1881.	11·16	54· 4	10· 8	25· 5	25·8	29·3.	S., strong.

So long as the atmospheric conditions are not very diverse, it is found that the agreement between theory and observation is very nearly perfect; the changes in the moon's parallax and declination, each producing their own separate effects with undeviating regularity, but when the atmospheric conditions change the effects become apparent. Thus, for the March Tides, lunar and anti-solar, transits between 4h. and 5h., P.M.

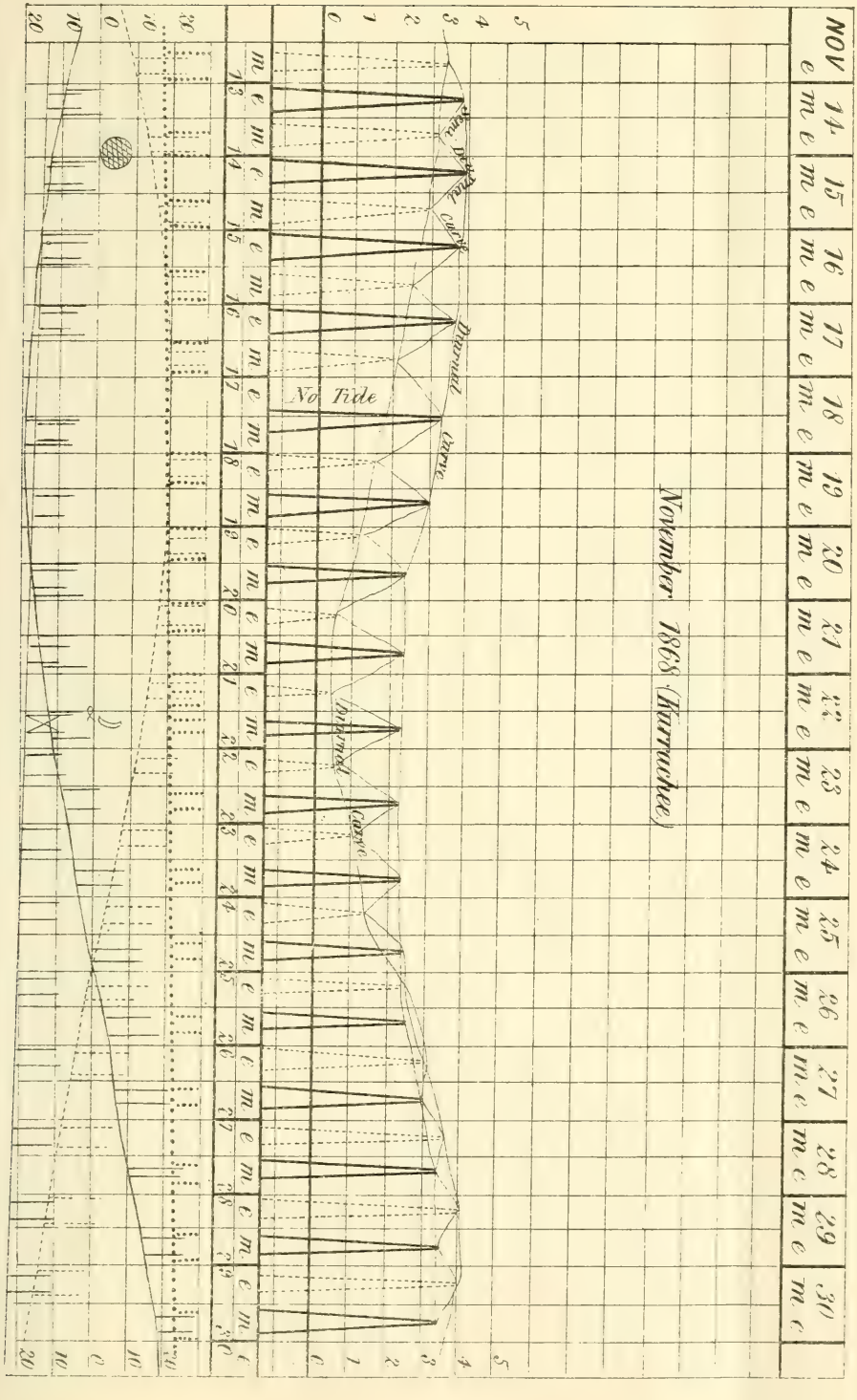
Years.	Moon's Trans.	Moon's Par.	Moon's Dec. S. desc.	Calculation.	Observation.	Barometer.	Wind, &c.
1877.	4·46	56· 2	25·34	20·10	20·7	29·5.	N.
1878.	4·12	58· 1	26·37	22· 5	22·3	29·8.	N.
1879.	4·31	59·19	25·15	22· 7	23·1	29·7.	S.W.
1880.	4·35	59·17	22·55	22· 8	23·9	29·7.	W.N.W., strong.
1881.	4·39	58·40	23· 6	22· 0	22·4	29·7.	S.W., fresh.
1882.	4·52	56·53	21· 3	21· 1	21·3	30·5.	W.S.W., fresh.

The last tide would have had its height augmented by the direction and force of the wind, but this was counteracted by the high barometric pressure.

In conclusion, enough has been said to show the progress made in accurate calculation, and the data upon which the effects of atmospheric conditions may be estimated. A similar method may be applied in the case of any other ports to which attention may be directed. For instance, in the case of Kurrachee, it is found that the diurnal inequality is very visible, when the moon or anti-moon is south of the equator at the instant of the transit, which occurs twelve hours previously. The configuration of land and water affects the course of the tides as certainly in the Indian as in the Atlantic Ocean ; everywhere it produces irregularities which cannot be ignored, when special tide-tables have to be calculated.

Plate XIX. represents the curves formed by the tides, as observed by W. Parkes, E.C., at Kurrachee, and referred to in the Report of the British Association for 1870. It shows, by means of the graphic process at the foot of the diagram, the law of the "diurnal inequality," for that place. For an explanation of this process see these *Proceedings, antea,* page 73. The law is this : when the moon is below the equator, the lunar tides (combined with the solar) are highest, and arrive at Kurrachee about twelve hours after the transit B. When the anti-moon is below the equator, the anti-lunar tides (combined with the anti-solar) are highest. The diurnal and semi-diurnal curves are also shown.

Proc. R.I.A. Plate XIX.



LXXXIX.—CONTRIBUTIONS TO THE THEORY OF SCREWS.

By ROBERT S. BALL, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.

[Read, November 13, 1882.]

THE theory of "emanants" in modern algebra (Salmon's *Higher Algebra*, 3rd ed., p. 108) is specially appropriate for throwing light on screw co-ordinate transformations. The present Paper relates to this subject.

Let $\alpha_1, \ldots \alpha_6$ denote the six co-ordinates of a twist or of a wrench. If we regard the amplitude of the twist or the intensity of the wrench as unity, then the six co-ordinates become the co-ordinates of the *screw*. For our present purpose we require the six co-ordinates to be independent variables, and therefore we shall regard them as the co-ordinates of the Dyname itself, not merely of the screw on which it reposes. To specify the screw five constants are required; one constant more gives the intensity of the Dyname, making six in all. The Dyname can thus be completely expressed by the six co-ordinates, of which each one is absolutely independent of the rest.

Let α' be the intensity of the Dyname on α; then α' is proportional to $\alpha_1, \ldots \alpha_6$ insomuch, that if the Dyname be replaced by another on the same screw α, but of intensity $x\alpha'$, the co-ordinates of this new Dyname will be $x\alpha_1, \ldots x\alpha_6$.

Let β be a second Dyname on another screw quite arbitrary as to its position and as to its intensity β'. Let the co-ordinates of β, referred to the same screws of reference, be $\beta_1, \ldots \beta_6$. If we suppose a Dyname of intensity $y\beta'$ on the screw β, then its co-ordinates will be $y\beta_1, \ldots y\beta_6$. Let us now compound together the two Dynames of intensities $x\alpha'$ and $y\beta'$ on the screws α and β. They will, according to the laws for the composition of twists and wrenches (*Theory of Screws*, p. 11), form a single Dyname on a third screw lying on the same cylindroid as α and β. The position of the resultant screw is such that it divides the angle between α and β into parts whose sines have the ratio of y to x. The intensity of the resulting Dyname is also determined (as in the parallelogram of force) to be the diagonal where x and y are the sides, and the angle between them is the angle between α and β. It is important to notice that in the determination of this resultant the screws of reference bear no part; the position of the resultant Dyname on the cylindroid as well as its intensity each depend solely upon the two original Dynames, and on the numerical magnitudes x and y.

We have now to form the co-ordinates of the resulting Dyname, or its components when decomposed along the six screws of reference. The first Dyname has a component of intensity $x\alpha_1$ on the front screw; and as the second Dyname has a component $y\beta_1$, it follows that the

sum of these two must be the component of the resultant. Thus we have for the co-ordinates of the resultant Dyname the expressions

$$xa_1 + y\beta_1, \ \ldots \ xa_6 + y\beta_6.$$

Let us suppose that without in any particular altering either of the Dynames α and β we make a complete change of the six screws of reference. Let the co-ordinates of α with regard to these new screws be $\lambda_1, \ldots \lambda_6$, and those of β be $\mu_1 \ldots \mu_6$. Precisely the same argument as has just been used will show that the composition of the Dynames $x\alpha'$ and $y\beta'$ will produce a Dyname whose co-ordinates are $x\lambda_1 + y\mu_1, \ \ldots \ x\lambda_6 + y\mu_6$. We thus see that the Dyname defined by the co-ordinates $xa_1 + y\beta_1, \ \ldots \ xa_6 + y\beta_6$, referred to the first group of reference screws is absolutely the same Dyname as that defined by the co-ordinates $x\lambda_1 + y\mu_1, \ \ldots \ x\lambda_6 + y\mu_6$ referred to the second group of reference screws, and that this must remain true for every value of x and y.

In general, let $\theta_1, \ \ldots \ \theta_6$ denote the co-ordinates of a Dyname in the first system, and $\phi_1, \ \ldots \ \phi_6$ denote those of the same Dyname in the second system. Let $f(\theta_1, \ \ldots \ \theta_6)$ denote any homogeneous function of the first Dyname, and let $F(\phi_1, \ \ldots \ \phi_6)$ be the same function transformed to the other screws of reference. Then we have

$$f(\theta_1, \ \ldots \ \theta_6) = F(\phi_1, \ \ldots \ \phi_6)$$

as an identical equation which must be satisfied whenever the Dyname defined by $\theta_1, \ \ldots \ \theta_6$ is the same as that defined by $\phi_1, \ \ldots \ \phi_6$. We must therefore have

$$f(xa_1 + y\beta_1, \ \ldots \ xa_6 + y\beta_6) = F(x\lambda_1 + y\mu_1, \ \ldots \ x\lambda_6 + y\mu_6).$$

These expressions being homogeneous, they may each be developed in ascending powers of $\frac{y}{x}$. But as the identity must subsist for every value of this ratio, we must have the coefficients of the various powers equal on both sides. The expression of this identity gives us a series of equations which are all included in the form—

$$\left(\beta_1 \frac{d}{da_1} + \ldots + \beta_6 \frac{d}{da_6}\right)^n f = \left(\mu_1 \frac{d}{d\lambda_1} + \ldots + \mu_6 \frac{d}{d\lambda_6}\right)^n F.$$

The functions thus arising are well known as "emanants" in the theory of modern algebra, and we have now proved that they are covariants of the original quantic. It is instructive to notice how intimately this branch of algebra is connected with the Dynamical conceptions in the theory of screws. The cases which we shall consider are those of $n = 1$ and $n = 2$. In the former case the emanant may be written

$$\beta_1 \frac{df}{da_1} + \ldots + \beta_6 \frac{df}{da_6}.$$

It will of course be understood that f is perfectly arbitrary, but results of any interest are only to be anticipated when f has been chosen with special relevancy to the Dyname itself, as distinguished from the influence due merely to the screws of reference. We shall first take for f the square of the intensity of the Dyname, the expression for which is found in the *Theory of Screws*, p. 34, to be

$$R = a_1^2 + \ldots + a_6^2 + 2a_1a_2(12) + \ldots,$$

where (12) denotes the cosine of the angle between the first and second screws of reference, which are here taken to be perfectly arbitrary. The second group of reference screws we shall take in a special form. They are to be located two by two on three intersecting rectangular axes (*Screws*, pp. 46, 172): so that

$$R = (\lambda_1+\lambda_2)^2 + (\lambda_3+\lambda_4)^2 + (\lambda_5+\lambda_6)^2.$$

Introducing these values, we have, as the first emanant,

$$\Sigma a_1\beta_1 + \Sigma(a_1\beta_2+a_2\beta_1)(12) = (\mu_1+\mu_2)(\lambda_1+\lambda_2) + (\mu_3+\mu_4)(\lambda_3+\lambda_4) + (\mu_5+\mu_6)(\lambda_5+\lambda_6);$$

but in the latter form the expression obviously denotes the cosine of the angle between α and β where the intensities are both unity; hence, *whatever be the screws of reference*, we must have for the cosine of the angle between the two screws the result

$$\Sigma a_1\beta_1 + \Sigma(a_1\beta_2+a_2\beta_1)(12),$$

an expression otherwise arrived at in *Trans.*, R. I. A., vol. xxv., Science, p. 306.

In general we have the following formula for the cosine of the angle between two Dynames multiplied into the product of their intensities:—

$$\tfrac{1}{2}\theta_1\frac{dR}{da_1} \quad . \quad . \quad . \quad + \tfrac{1}{2}\theta_6\frac{dR}{da_6}.$$

This expression, equated to zero, gives the condition that the two Dynames be rectangular.

If three screws, α, β, γ, be all parallel to the same plane, and if θ be a screw normal to that plane, then we must have

$$\theta_1\frac{dR}{da_1} \quad . \quad . \quad . \quad + \theta_6\frac{dR}{da_6} = 0,$$

$$\theta_1\frac{dR}{d\beta_1} \quad . \quad . \quad . \quad + \theta_6\frac{dR}{d\beta_6} = 0,$$

$$\theta_1\frac{dR}{d\gamma_1} \quad . \quad . \quad . \quad + \theta_6\frac{dR}{d\gamma_6} = 0.$$

Since a screw of a three-system can be drawn parallel to any direction, it will be possible to make any three of the quantities $\theta_1, \ldots \theta_6$ equal to zero. Hence, we have as the condition that the three screws, α, β, γ, shall be all parallel to a plane the evanescence of all the determinants of the type

$$\begin{vmatrix} \frac{dR}{d\alpha_1}, & \frac{dR}{d\alpha_2}, & \frac{dR}{d\alpha_3} \\ \frac{dR}{d\beta_1}, & \frac{dR}{d\beta_2}, & \frac{dR}{d\beta_3} \\ \frac{dR}{d\gamma_1}, & \frac{dR}{d\gamma_2}, & \frac{dR}{d\gamma_3} \end{vmatrix}.$$

If the three screws, α, β, γ, be co-cylindrical, these conditions must of course be fulfilled; but in this case the required conditions can be expressed more simply, for we must have equations of the type

$$\gamma_1 = \lambda\alpha_1 + \mu\beta_1,$$

. . . .

$$\gamma_6 = \lambda\alpha_6 + \mu\beta_6,$$

so that, if the three screws be co-cylindroidal, every determinant of the type

$$\begin{vmatrix} \alpha_1, & \beta_1, & \gamma_1 \\ \alpha_2, & \beta_2, & \gamma_2 \\ \alpha_3, & \beta_3, & \gamma_3 \end{vmatrix}$$

must be equal to zero.

The locus of the screws θ perpendicular to α is represented by the equation

$$\theta_1 \frac{dR}{d\alpha_1} \quad . \quad . \quad . \quad + \theta_6 \frac{dR}{d\alpha_6} = 0.$$

If we assume that the screws of reference are corecíprocal, then the equation just written can only denote all the screws reciprocal to the one screw whose co-ordinates are

$$\frac{1}{p_1}\frac{dR}{d\alpha_1}, \quad . \quad . \quad . \quad \frac{1}{p_6}\frac{dR}{d\alpha_6}.$$

It is manifest that all the screws perpendicular to a given line cannot be reciprocal to a single screw unless the pitch of that screw be infinite, otherwise the condition

$$(p_\alpha + p_\theta)\cos\phi - d\sin\phi = 0$$

could not be fulfilled. We therefore see that the co-ordinates just written can only denote those of a screw of infinite pitch parallel to α.

If x be a variable parameter, then the co-ordinates

$$\alpha_1 + \frac{x}{p_1} \cdot \frac{dR}{d\alpha_1}, \quad \ldots \quad \alpha_6 + \frac{x}{p_6} \cdot \frac{dR}{d\alpha_6}$$

must denote a screw of variable pitch x on the same screw as α. We are thus conducted by a more direct process to the results previously obtained (*Screws*, p. 100).

We may also consider that function of the co-ordinates of a Dyname which, being always proportional to the pitch, becomes exactly equal to the pitch when the intensity is equal to unity. More generally, we may define the function to be equal to the pitch multiplied into the square of the intensity, and it is easy to assign a physical meaning to this function. It is half the work done in a twist against a wrench, on the same screw, where the amplitude of the twist is equal to the intensity of the wrench. Referred to *any* co-ordinates, we denote this function by V expressed in terms of $\lambda_1 \ldots \lambda_6$. If we express the same function by reference to six coreciprocal axes with co-ordinates $\alpha_1 \ldots \alpha_6$, we have the result

$$p_1 \alpha_1^2 + \ldots p_6 \alpha_6^2 = V.$$

Forming now the first emanant, we have

$$2p_1\alpha_1\beta_1 + \ldots + 2p_6\alpha_6\beta_6 = \mu_1 \frac{dV}{d\lambda_1} \ldots + \mu_6 \frac{dV}{d\lambda_6};$$

but the expression on the left-hand side denotes the product of the two intensities into the vertical coefficient of the two screws; hence the right-hand member must denote the same. If, therefore, *after the differentiations* we make the intensities equal to unity, we thus have the following expression for the virtual coefficient between two screws λ and μ referred to *any* screws of reference whatever:—

$$\mu_1 \frac{dV}{d\lambda_1} \quad \ldots \quad + \mu_6 \frac{dV}{d\lambda_6} = 0.$$

Suppose, for instance, that λ is reciprocal to the first screw of reference, we have

$$\frac{dV}{d\lambda_1} = 0.$$

This can be verified in a somewhat instructive manner. We have

$$V = p\lambda'^2,$$

$$\frac{dV}{d\lambda_1} = \lambda'^2 \cdot \frac{dp}{d\lambda_1} + 2\lambda' p \frac{d\lambda'}{d\lambda_1};$$

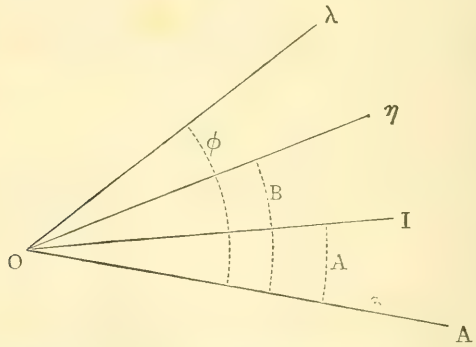
and, therefore, if λ be reciprocal to the first screw of reference, the formula to be proved is

$$\lambda'^2 \frac{dp}{d\lambda_1} + 2\lambda' p \frac{d\lambda}{d\lambda_1} = 0.$$

A few words will be necessary on the geometrical signification of the differentiation involved. Suppose a Dyname λ to be referred to six co-ordinate screws of absolute generality, and let us suppose that one of these co-ordinates, for instance λ_1, be permitted to vary, the corresponding situation of λ_1 also changes, and considering each one of the co-ordinates in succession, we thus have six routes established along which λ will travel in correspondence with the growth of the appropriate co-ordinate. Each route is, of course, a ruled surface; but the conception of a mere surface is not adequate to express the route. We must also associate a linear magnitude with each generator of the surface, which is to denote the pitch of the corresponding screw. Taking λ and another screw on one of the routes, we can draw a cylindroid through these two screws. It will now be proved that this cylindroid is itself the locus in which a moves, when the co-ordinate correlated thereto changes its value. Let θ be the screw arising from an increase in the co-ordinate λ_1; a wrench on θ of intensity θ'' has components of intensities $\theta''_1, \ldots \theta''_6$. A wrench on λ has components $\lambda''_1 \ldots \lambda''_6$. But from the nature of the case,

$$\frac{\theta''_2}{\lambda''_2} = \frac{\theta''_3}{\lambda''_3} \quad . \quad . \quad . \quad = \frac{\theta''_6}{\lambda''_6}.$$

If therefore θ'' be suitably chosen, we can make each of these ratios -1, so that when θ'' and λ'' are each resolved along the six screws of reference, all the components except $\theta''_1 - \lambda''_1$ shall neutralize. But this



can only be possible if the first reference screw lie on the cylindroid containing θ and λ. Hence we deduce the result that each of the six cylindroids must pass through the corresponding screw of reference; and thus we have a complete identification view of the route travelled

by a screw in correspondence with the variation of one of its co-ordinates.

Let the six screws of reference be 1, 2, 3, 4, 5, 6. Form the cylindroid $(\lambda, 1)$, and find that one screw η on this cylindroid which has with 2, 3, 4, 5, 6, a common reciprocal. Let the adjoining figure be a pencil of four rays parallel to four screws on the cylindroid. Let OA be parallel to one of the principal screws; $O\lambda$ be parallel to λ, $O\eta$ to η, and $O\iota$ to the first screw of reference. Let the angle $AO\iota$ be denoted by A, the angle $AO\eta$ by B, and the angle $AO\lambda$ by ϕ. To find the component λ_1 we must decompose λ', a twist on λ, into two components, one on η, the other on 1. The component on η can be completely resolved along the other five screws of reference, since the six form one system with a common reciprocal. If we denote by η' the component on η, we then have

$$\frac{\lambda'}{\sin(B-A)} = \frac{\lambda_1}{\sin(\phi-B)} = \frac{\eta'}{\sin(\phi-A)};$$

and if a and b be the pitches of the two principal screws on the cylindroid, we have for the pitch of λ the equation

$$p = a\cos^2\theta + b\sin^2\theta;$$

also $\dfrac{dp}{d\lambda_1} = \dfrac{dp}{d\phi}\cdot\dfrac{d\phi}{d\lambda_1}$, because the effect of a change in λ_1 is to move the screw along this cylindroid.

Now
$$\lambda_1 = \eta'\frac{\sin(\phi-B)}{\sin(\phi-A)},$$

and as the other co-ordinates are to be left unchanged, it is necessary that η' be constant, so that

$$\frac{d\lambda_1}{d\phi} = \eta'\frac{\sin(B-A)}{\sin^2(\phi-A)},$$

and hence
$$\frac{dp}{d\lambda_1} = (b-a)\sin 2\phi\,\frac{\sin^2(\phi-A)}{\eta'\sin(B-A)}.$$

Also
$$\frac{d\lambda'}{d\lambda_1} = \frac{d\lambda'}{d\phi}\cdot\frac{d\phi}{d\lambda_1} = -\cos(\theta-A).$$

Hence, substituting in the equation

$$\lambda'\frac{dp}{d\lambda'} + 2p\frac{d\lambda'}{d\lambda_1} = 0,$$

we deduce
$$a = b\tan\phi\tan A;$$

but this is the condition that λ and the first screw of reference shall be reciprocal (*Screws*, p. 37).

The emanants of the second degree are represented by the equation

$$\left(\beta_1\frac{d}{da_1}+\ .\ .\ .\ +\beta_6\frac{d}{da_6}\right)^2 f=\left(\mu_1\frac{d}{d\lambda_1}+\ .\ .\ .\ +\mu_6\frac{d}{d\lambda_6}\right)^2 F,$$

when F is the function into which f becomes transformed when the co-ordinates are changed from one set of screws of reference to another. If we take for f either of the functions already considered, these equations reduce to an identity; but retaining f in its general form, we can deduce some results of very considerable interest. The discussion which now follows was suggested by the very ingenious reasoning employed by Professor Burnside in the theory of orthogonal transformations (see Williamson's *Differential Calculus*, p. 412).

Let us suppose that we transform the function f from one set of co-reciprocal screws of reference to another system. Let $p_1 \ldots p_6$ be the pitches of the first set, and $q_1, \ldots q_6$ be those of the second set. Then we must have

$$p_1\beta_1^2+\ .\ .\ .\ +p_6\beta_6^2=q_1\mu_1^2+\ .\ .\ .\ +q_6\mu_6^2,$$

for each merely denotes the pitch of the Dyname multiplied into the square of its intensity. Multiply this equation by any arbitrary factor x and add it to the preceding, and we have

$$\left(\beta_1\frac{d}{da_1}+\ .\ .\ .\ +\beta_6\frac{d}{da_6}\right)^2 f+x(p_1\beta_1^2+\ .\ .\ .\ +p_6\beta_6^2)$$
$$=\left(\mu_1\frac{d}{d\lambda_1}+\ .\ .\ .\ +\mu_6\frac{d}{d\lambda_6}\right)^2 f+x(q_1\mu_1^2+\ .\ .\ .\ +q_6\mu_6^2).$$

Regarding $\beta_1, \ldots \beta_6$ as variables, the first member of this equation equated to zero would denote a certain screw system of the second degree. If that system were "central" it would possess a certain screw to which the polars of all other screws would be reciprocal, and its discriminant would vanish; but the screw β being absolutely the same as μ, it is plain that the discriminant of the second side must in such case also vanish. We thus see that the ratios of the coefficients of the various powers of x in the following determinant must remain unchanged when one co-reciprocal set of screws is exchanged for another. In writing the determinant we put 12 for $\frac{d^2 f}{da_1 \,.\, da_2}$, &c.

$$\begin{vmatrix} 11+xp_1, & 12 & , 13 & , 14 & , 15 & , 16 \\ 21 & , 22+xp_2, & 23 & , 24 & , 25 & , 26 \\ 31 & , 32 & , 33+xp_3, & 34 & , 35 & , 36 \\ 41 & , 42 & , 43 & , 44+xp_4, & 45 & , 46 \\ 51 & , 52 & , 53 & , 54 & , 55+xp_5, & 56 \\ 61 & , 62 & , 63 & , 64 & , 65 & , 66+xp_6 \end{vmatrix} = 0.$$

Take for instance the coefficient of x^5 divided by that of x^6, which is easily seen to be

$$\frac{1}{p_1}\cdot\frac{d^2f}{d\alpha_1^2}+\quad\ldots\quad+\frac{1}{p_6}\cdot\frac{d^2f}{d\alpha_6^2};$$

and we learn that this expression will remain absolutely unaltered provided that we only change from one set of co-reciprocals to another. In this f is perfectly arbitrary. Let us take it for instance to be the function R, or the square of the intensity, and we see that

$$\frac{1}{p_1}+\frac{1}{p_2}+\frac{1}{p_3}+\frac{1}{p_4}+\frac{1}{p_5}+\frac{1}{p_6}$$

must be an absolute constant so long as we are only concerned with a group of co-reciprocal screws. It is easily shown that this constant is zero, and thus we have a theorem otherwise proved in *Screws*, p. 149, and of which the present theory may be regarded as a generalization.

It will be readily seen that numerous results can be obtained from the different coefficients of the powers of x, the absolute term being for instance the Hessian. The functions added to the emanants might also be an arbitrary factor multiplied into R. Indeed if the discriminant were formed of the function

$$\left(\beta_1\frac{d}{d\alpha_1}+\ldots+\beta_6\frac{d}{d\alpha_6}\right)^2 f+x(p_1\beta_1^2+\ldots+p_6\beta_6^2)$$
$$+y(\beta_1^2+\ldots\beta_6^2+\ldots\ 2\beta_1\beta_2\,(12))$$

it would be easy to show that the ratios of the coefficients must be independent of the screw of reference so long as they were co-reciprocal, and thus a multitude of functions of f would be obtained which retain their form so long as the screws of reference are co-reciprocal. We might even discard this last condition by writing for the factor multiplied by x the most general value of the pitch multiplied by the square of the intensity.

XC.—Notes on the Flora of Lambay Island, County of Dublin.

By H. C. Hart, B.A.

[Read, November 13, 1882.]

The Island of Lambay is situated off the east coast of Dublin, at a distance of two and a-half miles from the nearest land at Portrane. It is somewhat hexagonal in shape, and contains an area of 595 acres, of which only a small part is under cultivation. The western is the cultivated portion of the island, which is devoted to dairy farming, and the butter of Lambay is famed for its excellence.

From Lambay Head, the eastern extremity, to the point north of Talbot's Bay on the west, is a distance of a mile and two-thirds, while the island is about a mile across from north to south in several places.

With the exception of a small strip of land at the harbour on the west, the coast is for the most part precipitous. From the western side the island rises to a height of a little over four hundred feet, and most of its eastern side is bound with cliffs from two to three hundred feet high. These cliffs are favourite breeding places for several species of sea-fowl, which resort here in great numbers from May to August. Here, also, the raven and peregrine-falcon breed annually. The island is well stocked with rabbits, which are preserved by the owner, Lord Talbot de Malahide. There are three families on Lambay, and there is an old castle, at one time the residence of Archbishop Ussher, in which, through the kindness of Mr. Dillon, the agent for the property, I was enabled to obtain accommodation during my visit.

Lambay is principally composed of porphyritic felstone of Lower Silurian age, and is of much geological interest. Graptolites and Bala fossils have been obtained, and there is a remarkable exposure of conglomerate lying below a sheet of Old Red Sandstone at sea level just inside Scotch Point. The formation of Lambay is, probably, continuous with that of the shore south of Portrane, near the Martello Tower.

Besides many former visits of a day's duration, I spent four days in the summer of 1881 on Lambay, and a similar time in the spring of the present year. During my last visit I had the company of my friend Mr. Richard Barrington, whose assistance rendered me better satisfied that the work was thoroughly done.

Owing to the absence of sandy shores or salt marshes, except in the smallest quantity, several common maritime plants do not appear in the flora. Again, with the exception of a couple of wells, and two or three small rivulets, there is no abode for marsh or aquatic plants, which are, accordingly, very poorly represented. On the other hand, some local species grow here in great abundance, while visitors in the early season are astonished by the extraordinary profusion of several showy flowers which, in their turn, deck the island with carpets of red and pink, mauve, white, and yellow. These are chiefly bluebells,

primroses, sea pink, red campion, sea campion, and sea feverfew. The abundance of red campion is a highly noticeable feature in Lambay.

It might appear that an island so well known and easy of access from Dublin as Lambay would be devoid of fresh interest, especially as it has been always a favourite resort for naturalists. To show that this is not the case, I will enumerate some rare or local plants which have not been previously noticed upon the island, and serve to show the interesting nature of its flora.

Arabis thaliana.
Parnassia palustris.
Geranium pusillum.
Erodium maritimum.
Trifolium striatum.
Vicia lathyroides.
Œnanthe crocata.
Torilis nodosa.
Apium graveolens.
Myosotis collina.
†*Hyoscyamus niger.*
Statice occidentalis.
Scilla verna.
†*Iris fœtidissima.*
Blysmus rufus.
Carex vulpina.
,, *extensa.*
Ophioglossum vulgatum.
Polypodium vulgatum, var. *semi-lacerum.*

Of the above, *Geranium pusillum* is the rarest; a single habitat in Clare, and a couple in Antrim, are the only certainly-known Irish localities for this plant, and its occurrence in Lambay is, therefore, highly important. *Iris fœtidissima* grows on cliffs covered with vegetation in three or four patches near one another on the north side of the island: this station is quite apart from cultivation, nor does the plant occur about the castle, or cottages, or elsewhere upon the island. It is a native plant all along the west of England, as far north as Durham, and belonging as it does to Mr. Watson's English type of distribution, which is well represented upon Lambay, it is, perhaps, unreasonable to challenge it. It occurs in considerable quantity in several places upon Howth and upon Ireland's Eye, but always near houses, as if introduced, and the bright-coloured seeds may, perhaps, have been carried from there to Lambay by birds. Mr. More does not believe it to be native in Ireland. *Trifolium striatum*, a very rare plant in Ireland, is plentiful on Lambay, where it appears to have been mistaken for *T. maritimum*. The lover of ferns will find, too, a handsome variety of the Polypody, *Polypodium semi-lacerum*, upon the same banks as the *Iris fœtidissima*.

The luxuriance of showy flowers has already been mentioned; the abundance of some either local or less common species is also a feature of interest. *Myosotis collina* is very abundant all round the margin, a little inside the rocky coast, while on the rocks themselves *Inula crithmoides* and *Crithmum maritimum* occur plentifully; *Scilla verna* forms the sod in many places, as at Scotch Point, near the sea; *Erodium maritimum* covers the ground with closely prostrate growth, especially on the dry, sandy soil about the rabbit-warren on the southern side; in thickets of brambles on the northern side of the island *Agrimonia*

eupatorium is unusually common, while in similar situations near the cliffs on the east, *Arum maculatum* is plentiful.

One of the most interesting "finds" I made on Lambay was that of an extraordinary luxuriant growth of *Ophioglossum vulgatum*, at the eastern end of the island, about a hundred and fifty yards inland southwards from Freshwater Bay, at the east side of the stream. This patch extends over more than an acre and a-half of ground, and is so closely grown that a sod of six inches square will often contain over a dozen fronds.

There is a distinct preference shown by several species for the southern shores of the island, or it might be nearer the truth to say that these, as a rule, avoid the northern coast from Lambay Head to Scotch Point: these are—

Viola hirta.
Geranium sanguineum.
Erodium maritimum.
Trifolium striatum.
Leontodon hirtus.
Cynoglossum officinale.
Lycopsis arvensis.
Statice occidentalis.
Beta maritima.
Arum maculatum.

This preference is due, no doubt, to some superiority of aspect or climate, since the situations are in other respects similar. Except this negative one, the north side has no characteristic peculiarity in its flora. It must be borne in mind that all the botanical interest of the island lies around the margin.

There are no indigenous trees upon Lambay; sycamore, ash, beech, and hawthorn have been introduced in the neighbourhood of the castle, but these have hardly spread themselves. Elder, blackthorn, and perhaps one sallow appear to be the only native shrubs. Furze occurs in a naturalized state, having spread to wild stations at the eastern side and about Raven's Rock; it was, however, introduced for fencing purposes about twenty-five years ago, as I am informed by Mr. Moncks, the caretaker. Brambles form a dense and tangled undergrowth in many parts of the island to the exclusion of other species.

The absence of several plants which are abundant on Howth, a promontory eight or ten miles from Lambay, with a similar flora, may be noticed. Amongst these are *Sarothamnus scoparius*, *Ulex europæus* and *U. nanus*, *Ononis arvensis*, *Artemisia vulgaris*, *Senecio sylvaticus*, *Salix repens*, &c.

I am confident that few plants have escaped my repeated searches over the island; nevertheless, the absence of some common ones was unexpected, for example :—

Stellaria holostea.
Bunium flexuosum.
Daucus carota.
Achillea millefolium.
Chrysanthemum leucanthemum.
Pedicularis sylvatica.
Carex stellulata.
C. trinervis.
Blechnum boreale.

The Lambay flora is a very natural one; there is little cultivation, and the introduced plants are few in number, sparingly established, and, as I think, easily detected. Disregarding several sub-species or varieties, the flora consists of 291 flowering plants and ferns, of which 33 species are probably not native.

FLORA OF LAMBAY.

RANUNCULACEÆ.

Ranunculus hederaceus (Linn.)—Raven's Well, and by the castle.
R. flammula (Linn.)—Frequent.
R. repens (Linn.)—Common.
R. bulbosus (Linn.)—About Scotch Point and elsewhere.
R. acris (Linn.)—Frequent.
R. ficaria (Linn.)—Common round the coast.
Caltha palustris (Linn.)—Raven's Well.

PAPAVERACEÆ.

[*Papaver somniferum* (Linn.)—Below Coastguard Station, an escape.]
**P. rhœas* (Linn.)—Cultivated fields near the harbour.
**P. dubium* (Linn.)—Do.

FUMARIACEÆ.

‡*Fumaria officinalis* (Linn.)—Cultivated ground near the harbour.

CRUCIFERÆ.

Cakile maritima (Scop.)—Sparingly south of harbour.
‡*Raphanus raphanistrum* (Linn.)—On the shore near the Coastguard Station, very closely approaching *R. maritimus*.
‡*Sinapis arvensis* (Linn.)—Cultivated ground and waste places near the castle.
†*S. alba* (Linn.)—With the last, scarce.
†*Sisymbrium officinale* (Scop.)—Borders of fields, pathways, &c.; probably native, but not plentiful.
Cardamine pratensis (Linn.)—Above Calico Bay.
C. hirsuta (Linn.)—In several places.
Arabis thaliana (Linn.) Banks above the sea at Broad Bay and Gillap. This is a rare and very local plant in Ireland. In the County Dublin I have only met with it upon Howth.
Nasturtium officinale (Brown.)—In two or three places by the brooks.
Cochlearia officinalis (Linn.)—Common.
? *Draba verna* (Linn.)—I believe I gathered withered stalks of this species, but am not certain.
**Thlaspi arvense* (Linn.)—A colony appeared in enclosed ground at the castle, 1882.
Capsella bursa-pastoris (Moench.)—Frequent.
‡*Senebiera coronopus* (Poir.)—By the harbour and cottages.

RESEDACEÆ.

‡*Reseda luteola* (Linn.)—Sparingly near the castle, and by the side of the field between it and Saltpan Bay.

VIOLACEÆ.

Viola hirta (Linn.)—Near the sea at Gouge Point; between Lambay Head and Sunk Island, near the sea in two places; by the well close to the castle, and elsewhere. Chiefly on the southern side of island.
V. sylvatica (Fries.)—Frequent. Chiefly *V. reichenbachiana.*
V. tricolor (Linn.)—Cultivated fields.

POLYGALACEÆ.

Polygala vulgaris (Linn.)—Common. Var. *depressa* (Wender) occurs at Raven's Rock.

CARYOPHYLLACEÆ.

Silene maritima (With.)—Abundant.
Lychnis diurna (Sibth.)—Covers many parts of the island with its rose-coloured blossoms in the earliest summer, especially amongst the thickets of blackberry a little inland.
L. flos-cuculi (Linn.)—By the stream into Carnoon Bay.
Cerastium tetrandrum (Curt.)—Pilots' Hill, &c.
C. glomeratum (Thuil.)—Banks by the sea on the north side.
C. triviale (Link.)—Common.
C. arvense (Linn.)—Plentiful.
Stellaria media (With.)—Frequent.
S. graminea (Linn.)—South-east side of Heath Hill, near the sea.
S. uliginosa (Murr.)—Raven's Well.
Honckenya peploides (Ehr.)—Sparingly near the harbour.
Sagina maritima (Don.)—Frequent; Scotch Point, &c.
S. procumbens (Linn.)—Frequent.
‡*Spergula arvensis* (Linn.)—Cultivated fields, frequent.
Lepigonum rupicola (More.)—Frequent.

HYPERICACEÆ.

Hypericum tetrapterum (Fries.)—In several places.
H. pulchrum (Linn.)—West side of island near the castle.

MALVACEÆ.

Malva sylvestris (Linn.)—Frequent.

LINACEÆ.

Linum catharticum (Linn.)—Common.

GERANIACEÆ.

Geranium sanguineum (Linn.)—On south and west side of island; north of Raven's Well.

G. molle (Linn.)—Frequent.

G. pusillum (Linn.)—I discovered a considerable quantity of this plant, one of the rarest in Ireland, at the south-west corner of the large field north of the castle.

G. dissectum (Linn.)—Frequent by the coast to the south of the harbour and elsewhere.

G. robertianum (Linn.)—In stony places behind the castle, sparingly.

Erodium cicutarium (Herit.)—Frequent.

E. maritimum (Sm.)—Especially abundant about the rabbit-warren at the south of the island; it forms a green sward frequently round the rabbit-holes, and appears to be the only plant permitted to do so. Frequent all round Lambay, except on the northern face, where it seems hardly able to exist.

Oxalis acetosella (Linn.)—Sparingly in shady ground near the castle.

LEGUMINOSÆ.

**Ulex europæus* (L.)—Introduced for fencing purposes, about twenty-five years ago. It has spread to wild stations on the eastern side, and about Raven's Rock.

Anthyllis vulneraria (Linn.)—Frequent.

‡*Medicago lupulina* (Linn.)—By a cottage, and on the borders of the large field north of the castle.

Trifolium pratense (Linn.)—Common, and I believe native on grassy banks by the sea.

T. arvense (Linn.)—Along the shore from the harbour to Scotch Point, and along the north side of the island in several places; not common.

T. striatum (Linn.)—Plentiful in pasturage above the harbour and along the shore to Scotch Point; east of the castle above a cottage and by the shore a little south of harbour beyond the Coastguard Station. In the "Flora Hibernica" *Trifolium maritimum* is said to grow on Lambay; probably the present species was mistaken for it.

T. repens (Linn.)—Frequent.

T. minus (Sm.)—Frequent.

Lotus corniculatus (Linn.)—Common.

†*Vicia hirsuta* (Koch.)—South-west side of island by the shore, and in cultivated fields near the Coastguard Station.

Vicia cracca (Linn.)—Banks by the shore at Talbot's Bay.

V. sepium (Linn.)—Frequent.

V. angustifolia (Roth.)—By the shore south of harbour, &c.; east coast of Lambay.

V. lathyroides (Linn.)—Under Tinian Hill, above the sea, on the east side of Lambay.

**Vicia sativa* (Linn.)—In several places amongst cultivated grounds.
Lathyrus pratensis (Linn.)—Scarce; above the sea at Calico Bay, and on dry, hilly ground south-east from the castle.

ROSACEÆ.

Prunus spinosa (Linn.)—South-east from the castle, not common.
Spiræa ulmaria (Linn.)—By the sides of the rivulets.
Agrimonia eupatoria (Linn.)—Very abundant in several places.
Alchemilla arvensis (Scop., Linn.)—Common.
Potentilla tormentilla (Schenk.)—Frequent.
P. reptans (Linn.)—Frequent.
P. anserina (Linn.)—Frequent.
Fragaria vesca (Linn.)—Frequent at the south-west part of the island.
Rubus carpinifolius (W. & N.)
R. villicaulis (W. & N.)
} These appeared to me to be the forms of brambles met with, the latter being very abundant.
Rosa spinosissima (Linn.)—Common.
R. canina (Linn.)—Frequent.
**Cratægus oxyacantha* (Linn.)—Not native.

LYTHRACEÆ.

Lythrum salicaria (Linn.)—By the sides of streams.

ONAGRACEÆ.

Epilobium hirsutum (Linn.)—Near the castle in two or three places.
E. parviflorum (Schreb.)—In several places.
E. palustre (Linn.)—Raven's Well, very sparingly.

HALORAGACEÆ.

Callitriche verna (Linn.)—Trinity Well, &c. Var. *platycarpa* (Scop.) Frequent.

CRASSULACEÆ.

Sedum anglicum (Huds.)—Common.
S. acre (Linn.)—Common.

SAXIFRAGACEÆ.

Parnassia palustris (Linn.)—Sparingly by the stream into Freshwater Bay about fifty yards from the cliffs, and at Raven's Well.

UMBELLIFERÆ.

Hydrocotyle vulgaris (Linn.)—By the rivulets.
Eryngium maritimum (Linn.)—At the harbour.

Apium graveolens (Linn.)—South-west shores of island, in plenty at Talbot's Bay.
Helosciadium nodiflorum (Koch.)—Frequent.
Ægopodium podagraria (Linn.)—Garden-ditch at the castle.
Œnanthe lachenalii (Gmel.)—Talbot's Bay.
Œ. crocata (Linn.)—At a well below the cottage a little south of Raven's Rock; on a bank behind the cottage immediately above the castle; and in a deep ditch south-east from the castle.
‡*Æthusa cynapium* (Linn.)—Near the castle.
Crithmum maritimum (Linn.)—Abundant.
Angelica sylvestris (Linn.)—Near the castle and elsewhere.
Heracleum sphondylium (Linn.)—Very abundant on cliffs at Saltpan Bay and elsewhere.
Torilis nodosa (Gaert.)—In the same locality as *Geranium pusillum*.
Chærophyllum sylvestris (Linn.)—Shady ground about the castle.
Conium maculatum (Linn.)—By the shore on the south-west side of the island; apparently native a little north of Raven's Well on the hill side; and near the castle.

ARALIACEÆ.

Hedera helix (Linn.)—Frequent.

CAPRIFOLIACEÆ.

Sambucus nigra (Linn.)—A characteristic plant, and the only conspicuous native shrub on Lambay. Abundant on banks above Broad Bay and Saltpan Bay; Knockbane; Seal hole, &c.
Lonicera periclymenum (Linn.)—Frequent.

RUBIACEÆ.

Galium saxatile (Linn.)—Heath Hill, &c.; not common.
G. verum (Linn.)—Frequent.
G. aparine (Linn.)—Frequent, especially among shingle on the shore on the south-west.
‡*Sherardia arvensis* (Linn.)—Cultivated field south of castle.

DIPSACEÆ.

Scabiosa succisa (Linn.)—Very common.

COMPOSITÆ.

Carduus tenuiflorus (Curt.)—Common.
C. lanceolatus (Linn.)—Frequent.
C. palustris (Linn.)—Frequent.
C. arvensis (Curt.)—Frequent.
Carlina vulgaris (Linn.)—Frequent.
Arctium intermedium (Lange.)—Frequent.
Centaurea nigra (Linn.)—Frequent.

‡*Chrysanthemum segetum* (Linn.)—Sparingly in the same field as *Sherardia arvensis.*

Matricaria inodora (Linn.)—Very abundant.

**Artemisia absinthium* (Linn.)—Established in the neighbourhood of two or three cottages. Much used "for the stomach" by the Irish peasantry, and introduced from the mainland. This plant is not native on the east coast of Ireland.

Filago germanica (Linn.)—Sparingly on banks above the sea in two or three places on the north side.

Senecio vulgaris (Linn.)—Frequent.

S. jacobæa (Linn.)—Frequent.

Inula crithmoides (Linn.)—Common on most of the coast, except the northern side.

I. pulicaria (Linn.)—In damp places; frequent.

Bellis perennis (Linn.)—Frequent.

Aster tripolium (Linn.)—Only at the south-west side of the island.

Tussilago farfara (Linn.)—In several places.

Eupatorium cannabinum (Linn.)—Gillap on the north, and near the seal-hole on the south-east side.

†*Lapsana communis* (Linn.)—Cultivated ground only.

Hypochæris radicata (Linn.)—Common.

Leontodon hirtus (Linn.)—By the shore on the south side and south-west side of island.

L. autumnalis (Linn.)—Common.

Taraxacum officinale (Wigg.)—South and west side of island.

Sonchus oleraceus (Linn.)
S. asper (Hoffin.)
S. arvensis (Linn.)
} Frequent; *S. arvensis* grows in a native situation on the south-west shore.

Hieracium pilosella (Linn.)—Common.

Campanulaceæ.

Jasione montana (Linn.)—Rocky ground at Gillap; scarce.

Campanula rotundifolia (Linn.)—Frequent.

Ericaceæ.

Erica cinerea (Linn.)—Common.

Calluna vulgaris (Salist.)—Common.

Note.—*Erica tetralix*, which is not upon Lambay, requires a moister climate and a greater extent of mountainous country than the above species; it is, certainly, more local on the east side of Ireland than is generally supposed. Its absence from Howth is remarkable, and I have recently observed that it is either rare or quite wanting on the Knockmeledown and Cummeragh Mountains in the County Waterford. I spent a day upon each of these groups without meeting with it. Again, along the mountainous coast of Waterford, from Tramore to Youghal, where the other species are abundant, *E. tetralix* does not occur; whereas in similar situations in the north or west of Ireland it would, undoubtedly, be present. It is common, however, on the Wicklow and Dublin Mountains.

GENTIANACEÆ.

Erythræa centaurium (Pers.)—Var. *pseudo-latifolia*. Frequent.

SOLANACEÆ.

Solanum dulcamara (Linn.)—By the rivulet into Carnoon Bay.
†*Hyoscyamus niger* (Linn.)—A good-sized patch near the seal-hole on the south-east side of the island.

SCROPHULARIACEÆ.

Scrophularia nodosa (Linn.)—Very sparingly in Thornchase Valley.
†*Veronica hederifolia* (Linn).—Ditch-banks of the large field north of castle and below coastguard station.
‡*V. polita* (Fries.)
‡*V. agrestis* (Linn.)
} Below the Coastguard Station and near the cottages in two or three places, but apparently introduced.
* *V. buxbaumii* (Ten.)—By a cottage east of the castle.
V. arvensis (Linn.)—Common.
V. serpyllifolia (Linn.)—Near the castle, &c.
V. officinalis (Linn.)—Common.
V. chamædrys (Linn.)—Common.
V. anagallis (Linn.)—In a deep ditch south-east from the castle.
V. beccabunga (Linn.)—Frequent.
Euphrasia officinalis (Linn.)—Very scarce, Raven's Rock only.
†*Bartsia odontites* (Huds.)—Frequent about cultivation.
‡*Rhinanthus crista-galli* (Linn.)—A few plants on the border of a field near the castle.

LABIATÆ.

Mentha hirsuta (Linn.)—Frequent.
Thymus serpyllum (Fries.)—Common.
Nepeta glechoma (Benth.)—Common.
Prunella vulgaris (Linn.)—Common.
†*Galeopsis tetrahit* (Linn.)—Cultivated fields.
‡*Lamium amplexicaule* (Linn.)—Cultivated ground near the Coastguard Station.
†*L. incisum* (Willd.)—Near the Coastguard Station, and by a cottage, east from the castle.
†*L. purpureum* (Linn.)—About the castle.
Teucrium scorodonia (Linn.)—Common.

BORAGINACEÆ.

Myosotis cæspitosa (Schultz.)—By a rivulet a little south of the castle.
M. palustris (With.)—In one deep ditch south-east from the castle.
M. arvensis (Hoffm.)—South and east side of island.
M. collina (Reich.)—Very abundant all round the island, though not occuring far from the sea. A characteristic feature in the Lambay Flora.

Myosotis versicolor (Reich.)—Frequent.
Lycopsis arvensis (Linn.)—Chiefly on the south-east side.
**Symphytum officinale* (Linn.)—On a ditch-bank behind the herd's cottage.
Cynoglossum officinale (Linn.)—South-east side of the island, near the sea.

PRIMULACEÆ.

Primula vulgaris (Huds.)—Common.
P. veris (Linn.)—Near Trinity Well, and in a meadow near the castle (Miss Monks.)
Anagallis arvensis (Linn.)—About rabbit burrows near the coast, frequent. Also in cultivated fields.
A. tenella (Linn.)—About the Raven's Well.
Glaux maritima (Linn.)—South-west shore, Carnoon and Talbot's Bay.
Samolus valerandi (Linn.)—Not unfrequent.

PLUMBAGINACEÆ.

Armeria maritima (Willd.)—Common.
Statice occidentalis (Lloyd.)—Rocky coast south-west of Lambay Head. About Tayleur Bay.

PLANTAGINACEÆ.

Plantago major (Linn.)—About the castle.
P. lanceolata (Linn.)—Common.
P. maritima (Linn.)—Common.
P. coronopus (Linn.)—Common.

CHENOPODIACEÆ.

Salsola kali (Linn.)—Near the harbour.
Beta maritima (Linn.)—Abundant on the southern shore.
‡*Chenopodium album* (Linn.)—Cultivated and waste ground.
Atriplex angustifolia (Sm.)—Talbot's Bay, &c.
A. deltoidea (Bab.)—Talbot's Bay, &c.
A. babingtonii (Woods.)—Frequent.
A. littoralis (Linn.)—A little south of the castle. I did not meet with this plant during my last visit to Lambay, but gathered it in 1881.

POLYGONIACEÆ.

Rumex nemorosus (Schrad.)—About the castle.
R. obtusifolius (Aust.)—Frequent.
R. crispus (Linn.)—Frequent.
R. acetosa (Linn.)—Frequent.
R. acetosella (Linn.)—Frequent.
†*Polygonum convolvulus* (Linn.)—Cultivated fields.

Polygonum aviculare (Linn.)—Frequent
P. raii (Bab.)—Near the north of the harbour.
P. persicaria (Linn.)—Frequent.

EUPHORBIACEÆ.

‡*Euphorbia helioscopia* (Linn.)—Cultivated fields near the castle.
‡*E. peplus* (Linn.)—Cultivated fields near the castle.

URTICACEAE.

Urtica dioica (Linn.)—The nettles in Saltpan Bay are ranker and more venomous than any I ever met with; the effects of their stings do not pass off for a couple of days.
‡*U. urens* (Linn.)—In several places.

AMENTIFERÆ.

‡*Salix viminalis* (Linn.)—Near the castle, but probably introduced.
†*S. cinerea* (Linn.)—Near the castle, perhaps introduced.

ARACEÆ.

Arum maculatum (Linn.)—South and south-east sides near the sea. Common.

LEMNACEÆ.

Lemna minor (Linn.)—Raven's Well.

NAIADACEÆ.

Zostera marina (Linn.)—Low water at spring-tides a little south of the harbour.

ALISMACEÆ.

Triglochin palustre (Linn.)—Sparingly at Bishop's Bay.
T. maritimum (Linn.)—Sparingly at Bishop's Bay.

ORCHIDACEÆ.

Orchis latifolia (Linn.)—One plant at Raven's Well, where it was detected by Mr. Barrington; but Miss Monks assured me it was usually plentiful there.

IRIDACEÆ.

†*Iris fœtidissima* (Linn.)—Banks above Saltpan Bay in three places, and at the shore level. See introduction.
†*Iris pseudacorus* (Linn.)—Bishop's Bay on the southern side. I have appended the mark of suspicion in deference to the opinion of Mr. Moore.

LILIACEÆ.

Scilla verna (Huds.)—Abundant on dry grassy banks on the westward side of the island and elsewhere.

Scilla nutans (Sm.)—Very abundant on Lambay, and lending a colour to the slopes in the spring. The white variety of the bluebell occurs rarely.

JUNCACEÆ.

Luzula campestris (W. C.)—Frequent.
Juncus maritimus (Sm.)—South-west side, at Carnoon Bay and Talbot's Bay.
J. conglomeratus (Linn.)—East side of Lambay.
J. glaucus (Sibth.)—By the rivulet into Freshwater Bay, and on the south-east side.
J. acutiflorus (Ehrh.)—Frequent.
J. lamprocarpus (Ehrh.)—At Scotch Point.
J. supinus (Mœnch.)—About the castle.
J. bufonius (Linn.)—Frequent.
J. gerardi (Lois.)—(*J. compressus*, Jacq. var.) Carnoon Bay.

CYPERACEÆ.

Schœnus nigricans (Linn.)—Talbot's Bay and Carnoon Bay.
Blysmus rufus (Link.)—Carnoon Bay; first observed by Mr. Barrington.
Scirpus savii (S. & M.)—Raven's Well; stream into Freshwater Bay; south-west side of island.
Eriophorum angustifolium (Roth.)—Raven's Well.
Carex disticha (Huds.)—By Freshwater Bay brook, and in several marshes at the west side.
C. arenaria (Linn.)—Carnoon Bay and Bishop's Bay.
C. vulpina (Linn.)—Bishop's Bay.
C. vulgaris (Fries.)—Pilot's Hill.
C. glauca (Scop.)—In several places.
C. præcox (Jacq.)—Frequent, chiefly by the coast.
C. panicea (Linn.)—Marshy ground east of Knockbane.
C. distans (Linn.)—Common on the south and west shores.
C. extensa (Good.)—Carnoon Bay, and elsewhere on the south-west shore.
C flava (Linn.)—By the stream into Freshwater Bay.
C. hirta (Linn.)—Raven's Well, and in several places near the castle.

GRAMINEÆ.

Anthoxanthum odoratum (Linn.)—Common.
Digraphis arundinacea (Trin.)—Sparingly by a heavy ditch south-east from the harbour.
†*Alopecurus pratensis* (Linn.) } Fields about the castle.
‡*Phleum pratense* (Linn.) }
Agrostis vulgaris (With.)—Frequent.
A. alba (Linn.)—Frequent.
A. canina (Linn.)—Frequent.
Aira flexuosa (Linn.)—Frequent.
†*A. cæspitosa* (Linn.)—Frequent.
A. caryophyllea (Linn.)—Frequent.

Aira præcox (Linn.)—Frequent.
Arrhenatherum avenaceum (Beauv.)—Common.
Holcus mollis (Linn.)—Northern coast, in two or three places.
H. lanatus (Linn.)—Frequent.
Triodia decumbens (Beauv.)—Hilly ground behind the castle.
Molinia cærulea (Mœnch.)—Scarce, a little east from the castle.
Glyceria fluitans (Brown.)—By the stream into Freshwater Bay.
Sclerochloa maritima (Lindl.)—Frequent.
S. rigida (Link.)—Walls of castle, farm-yard, and pier-wall.
Poa annua (Linn.)—Frequent.
P. pratensis (Linn.)—In several places.
P. trivialis (Linn.)—Near the castle.
Briza media (Linn.)—A little west of the harbour.
Cynosurus cristatus (Linn.)—Frequent.
Dactylis glomerata (Linn.)—Frequent.
Festuca sciuroides (Roth.)—Walls by the castle; shore between chapel and Coastguard Station.
F. ovina (Linn.), et *F. duriuscula* (Linn.)—Frequent.
F. elatior (Linn.)—South-west side at Carnoon Bay.
Bromus mollis (Linn.)—Common.
Brachypodium sylvaticum (R. & S.)—Frequent along the southern cliffs.
Triticum repens (Linn.)—Carnoon Bay.
T. junceum (Linn.)—Near the harbour.
Lolium perenne (Linn.)—Frequent.
Nardus stricta (Linn.)—Frequent.

Filices.

Pteris aquilina (Linn.)—Frequent.
Asplenium marinum (Linn.)—New House; Tayleur Bay; Saltpan Bay.
A. adiantum nigrum (L.)—Rocky places about the castle; Calico Bay; Lambay Head.
Athyrium filix-fœmina (Bernh.)—Near Raven's Well; north side of Knockbane.
Scolopendrium vulgare (Sm.)—Calico Bay and Saltpan Bay.
Aspidium angulare (Willd.)—Grassy cliffs above Calico Bay; rocky places above the castle.
Lastræa filix-mas (Presl.)—North side of island at Knockbane, &c.
L. dilata (Presl.)—Sparingly by the sea in Saltpan Bay.
Polypodium vulgare (Linn.)—Common on the north side; the variety *semi-lacerum* occurs at Calico Bay. This is the form that is usually called *P. cambricum* in Ireland, from which it differs in bearing copious fructification and in other respects. I mention this to correct the statement made in the "Catalogue of Dublin and Wicklow Plants," that *P. cambricum* occurs in the Dargle. The Dargle fern is *P. semi-lacerum*, and I doubt if true *P. cambricum* has ever been gathered in Ireland. My brother, Mr. G. V. Hart, who has long cultivated the Irish ferns, has never met with it.

Ophioglossum vulgatum (Linn.)—Remarkably abundant on the northern slope of Pilot's Hill.

EQUISETACEÆ.

Equisetum arvense (Linn.)—Ditch-banks east of the castle.

It has occurred to me that a comparison between the floras of an island upon the east and one upon the west coast of Ireland would be of interest. Reliable means for such a comparison are available in Mr. More's "Report on the Flora of Inish-Bofin, Co. Galway,"[1] an island which lies almost exactly in the same latitude upon the west of Ireland as Lambay does upon the east. These islands are both devoid of limestone, and there is no geological dissimilarity which would entail any important difference in their floras. Their coast lines are alike in character, and their difference in elevation is trifling, Lambay being about a hundred feet higher than Inish-Bofin. Inish-Bofin has, however, about four times the area of Lambay, and the western island has also a great superiority in possessing "four small lakes and a few pools with a considerable extent of moist and boggy ground producing a fair proportion of water plants, sedges, rushes," &c. Lambay has, as we have seen, neither lake nor turf-bog, and very little ground suitable for any of the marsh or aquatic species. The contrast which I propose to draw has for its object the illustration of the differences arising from the climates of the two coasts, and geographical distribution. Probably these influences alone are the causes why many of the Lambay plants do not or could not exist upon Inish-Bofin. On the other hand many of the Inish-Bofin plants which do not occur upon Lambay are absent, in all likelihood, simply from surface conditions and the want of sufficient water.

Prominent amongst them are :—

Ranunculus heterophyllus, et vars.,
Drosera rotundifolia,
Myriophyllum alterniflorum,
Galium palustre,
Montia fontana,
Menyanthes trifoliata,
Polygonum amphibium,
Narthecium ossifragum,
Potamogeton pusillus,
P. natans.
P. polygonifolius,
Phragmites communis,
Eleocharis palustris,
Carex ampullacea,
Equisetum limosum.

These are all found—for instance, upon the adjacent promontory of Howth, and are unimportant for the purpose which I have in view. They will be omitted in my comparative list as being merely accidental absentees.

While upon this subject I will venture to make a remark on the comparison which Mr. More institutes in the above-mentioned "Report" between the flora of Inish-Bofin and that of the Isles of Aran, Galway Bay; taking his data for the latter from a list published by me in 1875—a list which is confessedly incomplete. In that publication

I laid particular stress upon "the absence of turfy bogs and scarcity of damp ground which entails a great want of marsh and heath plants, sedges, and rushes," &c. The result of this is that Mr. More can enumerate ninety-two plants upon Bofin which do not occur upon Aran, against 161 Aran plants which are absent from Bofin. Of these, the majority are, in all probability, absent from Aran in consequence of this accidental want of marshy ground and in no respect from climate, geological structure, or geographical situation. The omission of this consideration renders the contrast between the two floras less strikingly in favour of the Aran limestone flora than it may be fairly estimated by attaching weight to the absence of unimportant plants.

Mr. More enumerates 303 varieties, or, say 295 species, as found upon Inish-Bofin. My Lambay list contains 291 species. Deducting from each of these totals those plants which are probably introduced, there remain 252 native species for Bofin, 258 for Lambay. Considering the superior size of Inish-Bofin and its much more diversified surface-conditions, the majority in favour of Lambay illustrates well the richer flora of the east of Ireland. A few plants, such as *Sisymbrium officinale*, *Capsella bursa-pastoris*, *Galium aparine*, and three species of trefoil are, I believe, native on Lambay, though most likely only colonists in the far west of Ireland.

In the following comparative lists several commoner aquatic species already mentioned are omitted from the Bofin plants, as not tending to illustrate the essential differences between the two floras:—

COMPARATIVE VIEW OF FLORAS OF INISH-BOFIN AND LAMBAY,

Including only Plants probably native.

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
Ranunculaceæ.	
Ranunculus ficaria.	
Caltha palustris.	
Nymphæaceæ.	
	Nuphar luteum.
Cruciferæ.	
Sisymbrium officinale.	
Arabis thaliana.	
Draba verna.	
Cistaceæ.	
	Helianthemum guttatum.
Violaceæ.	
Viola hirta.	*Viola palustris.*
V. tricolor.	*V. canina.*

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
	POLYGALACEÆ.
Polygala vulgaris, typ.	
	ELATINACEÆ.
	Elatine hexandra.
	CARYOPHYLLACEÆ.
Lychnis diurna.	*Spergularia salina.*
Cerastium arvense.	
Stellaria media.	
S. graminea.	
S. uliginosa.	
Honckenya peploides.	
Sagina maritima.	
	LINACEÆ.
	Radiola millegrana.
	HYPERICACEÆ.
	Hypericum androsæmum.
	H. elodes.
	GERANIACEÆ.
Geranium sanguineum.	
G. pusillum.	
G. dissectum.	
Erodium maritimum.	
	LEGUMINOSÆ.
Trifolium repens.	Mr. More considers these three clovers as probably introduced on Inish-Bofin.
T. pratense.	
T. minus.	
†*Vicia hirsuta.*	
V. lathyroides.	
	ROSACEÆ.
Fragaria vesca.	*Comarum palustre.*
Alchemilla arvensis.	
Agrimonia eupatorium.	
	ONAGRACEÆ.
Epilobium hirsutum.	*Epilobium montanum.*
	E. tetragonum.
	LYTHRACEÆ.
	Peplis portula.

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
SAXIFRAGACEÆ.	
Parnassia palustris.	*Saxifraga umbrosa.*
CAPRIFOLIACEÆ.	
Sambucus nigra.	
UMBELLIFERÆ.	
Eryngium maritimum.	*Daucus carota.*
Apium graveolens.	*Helosciadium inundatum.*
Helosciadium nodiflorum.	
Œnanthe lachenalii.	
Œ. crocata.	
Torilis nodosa.	
Chærophyllum sylvestre.	
Conium maculatum.	
RUBIACEÆ.	
Galium aparine.	
COMPOSITÆ.	
Carduus tenuiflorus.	†*Centaurea scabiosa.*
Carlina vulgaris.	*Gnaphalium uliginosum.*
Filago germanica.	*Senecio sylvaticus.*
Inula crithmoides.	*Achillea ptarmica.*
Eupatorium cannabinum.	*A. millefolium.*
CAMPANULACEÆ.	
	Lobelia dortmanna.
ERICACEÆ.	
	Erica tetralix.
GENTIANACEÆ.	
	Gentiana campestris.
CONVOLVULACEÆ.	
	Convolvulus sepium.
SOLANACEÆ.	
Solanum dulcamara.	
Hyoscyamus niger.	

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
Scrophulariaceæ.	
Scrophularia nodosa.	*Rhinanthus crista-galli.*
†*Veronica hederifolia.*	*Pedicularis palustris.*
	P. sylvatica.
	Scrophularia aquatica.
Labiatæ.	
Nepeta glechoma.	*Stachys palustris.*
†*Lamium incisum.*	*Scutellaria minor.*
†*L. purpureum.*	
Boraginaceæ.	
Myosotis palustris.	
M. collina.	
M. versicolor.	
Lycopsis arvensis.	
Cynoglossum officinale.	
Lentibularineæ.	
	Pinguicula vulgaris.
Primulaceæ.	
Primula veris.	*Centunculus minimus.*
Anagallis arvensis.	
Plumbaginaceæ.	
Statice occidentalis.	
Plantaginaceæ.	
	Litorella lacustris.
Chenopodiaceæ.	
Beta maritima.	
Atriplex littoralis.	
Polygonaceæ.	
Rumex nemorosus.	*Polygonum hydropiper.*
Polygonum raii.	
Empetraceæ.	
	Empetrum nigrum.
Callitrichaceæ.	
	Callitriche hamulata.

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
URTICACEÆ.	
Urtica dioica.	
AMENTIFERÆ.	
†*Salix cinerea.*	*Populus tremula.*
	Salix aurita.
	S. repens.
	Myrica gale.
LILIACEÆ.	
Scilla verna.	
Scilla nutans.	
CONIFERÆ.	
	Juniperus nana.
ORCHIDACEÆ.	
Orchis latifolia.	*Orchis maculata.*
IRIDACEÆ.	
Iris fœtidissima.	
ALISMACEÆ.	
Triglochin maritimum.	
NAIADACEÆ.	
	Potamogeton pectinatus.
AROIDEÆ.	
Arum maculatum.	
TYPHACEÆ.	
	Sparganium affine.
RESTIACEÆ.	
	Eriocaulon septangulare.
JUNCACEÆ.	
Luzula campestris.	*Luzula multiflora.*
Juncus maritimus.	*Juncus squarrosus.*
J. glaucus.	

Lambay Plants not on Inish-Bofin.	Inish-Bofin Plants not on Lambay.
Cyperaceæ.	
Blysmus rufus.	*Scirpus fluitans.*
Carex disticha.	*Rhynchospora alba.*
C. vulgaris.	*Eleocharis multicaulis.*
C. vulpina.	*Carex pulicaris.*
C. hirta.	*C. stellulata.*
	C. binervis.
Gramineæ.	
Digraphis arundinacea.	*Psamma arenaria.*
†*Alopecurus pratensis.*	*Calamagrostis epigejos.*
†*Aira cæspitosa.*	*Kœleria cristata.*
Holcus mollis.	*Sclerochloa loliacea.*
Sclerochloa rigida.	*Festuca pratensis.*
Briza media.	
Festuca sciuroides.	
Triticum junceum.	
Filices.	
Scolopendrium vulgare.	*Asplenium ruta-muraria.*
Aspidium angulare.	*Blechnum boreale.*
Ophioglossum vulgatum.	*Lastræa æmula.*
	Osmunda regalis.
Lycopodiaceæ.	
	Isoetes echinospora.

Thus Lambay contains ninety-one, and Inish-Bofin sixty-four characteristic peculiar plants. In order to understand more thoroughly the different natures of the two floras, I will arrange them according to Mr. Watson's types. The Lambay flora will be found to contain forty-nine species of the British or commonest type not occurring upon Bofin, as against fifty-five British type plants on Bofin not occurring upon Lambay. And this is what might have been foreseen, the larger island containing the greater variety of common species. There are about one hundred and sixty-five 'British type' species common to both islands.

The undermentioned species peculiar to either island belong to Watson's English type, or are "inclining to" his English type :—

Lambay.	Bofin.
Sisymbrium thalianum.	Nuphar lutea.
Viola hirta.	Elatine hexandra.
Cerastium arvense.	Hypericum androsæmum.
Geranium sanguineum.	H. elodes.

LAMBAY.	BOFIN.
Geranium pusillum.	†Centaurea scabiosa.
Trifolium striatum.	Gnaphalium uliginosum.
T. arvense.	Convolvulus sepium.
T. minus.	Scrophularia aquatica.
Agrimonia eupatorium.	Scutellaria minor.
Epilobium hirsutum.	Centunculus minimus.
Sambucus nigra.	Calamagrostis epigejos.
Apium graveolens.	Sclerochloa loliacea.
Helosciadium nodiflorum.	
Œnanthe crocata.	
Œ. lachenalii.	
Torilis nodosa.	
Eupatorium cannabinum.	
Carlina vulgaris.	
Carduus tenuiflorus.	
Solanum dulcamara.	
Hyoscyamus niger.	
Cynoglossum officinale.	
Myosotis palustris.	
Primula veris.	
Anagallis arvensis.	
Beta maritima.	
Iris fœtidissima.	
Juncus glaucus.	
J. maritimus.	
Arum maculatum.	
Carex disticha.	
C. hirta.	
Sclerochloa rigida.	
Briza media.	
Aspidium angulare.	

There are, besides, three English, or inclining to English type species common to both, viz. :—*Vicia augustifolia*, *Lythrum salicaria*, *Samolus valerandi*. These columns show well the decrease in numbers of this type on the western coast—15 to 38, or as 1 to $2\frac{1}{2}$.

Next in importance is the Atlantic type; its members stand as follows :—

LAMBAY.	BOFIN.
Erodium maritimum.	Lastræa æmula.
Inula crithmoides.	
Statice occidentalis.	
Scilla verna.	

And five species common to both islands, viz. :—

Lepigonum rupicola.
Sedum anglicum.
Crithmum maritimum.
Scirpus savii.
Asplenium marinum.

This is rather surprising; but it will be found that Watson's Atlantic or western type is anomalously so-called in Ireland, being at least as well represented on the eastern as on the western coast, so that the insular floras reveal a somewhat unexpected truth. There are, however, two highly interesting plants upon Inish-Bofin which do not fall under any of Watson's types, *Helianthemum guttatum* and *Saxifraga umbrosa*. These and others of the so-called Hibernian type which do not occur in Great Britain may be regarded as the extremest group of the Atlantic type in the British Islands.

With Highland and northern plants Lambay is sparingly supplied, two species of the latter alone being met with, while nine occur upon Bofin.

Lambay.	Bofin.
Parnassia palustris.	Comarum palustre.
Blysmus rufus.	Lobelia dortmanna.
	Gentiana campestris.
	Pinguicula vulgaris.
	Empetrum nigrum.
	Juniperus nana.
	Eriocaulon septangulare.
	Sparganium affine.
	Isoetes echinospora.

This, again, exemplifies the condition of things upon the mainland, both these types being much better represented and descending lower upon the west than upon the east coast of Ireland, and is due, no doubt, to the damper and more equal climate. Most of the remaining species peculiar to Bofin are more universally prevalent in the west than in the east of Ireland, amongst which may be mentioned :—

Bofin.

Viola palustris.
Achillea ptarmica.
Erica tetralix.
Myrica gale.
Litorella lacustris.
Callitriche hamulata.
Rhynchospora alba.
Eleocharis multicaulis.
Osmunda regalis.

POSTSCRIPT.—Since writing the above, Mr. More has drawn my attention to a paragraph in Dalton's "History of Ireland," where some Lambay plants are enumerated. Amongst these are a few which I did not meet with, and which are probably erroneously included. The records are taken from the "Irish Flora," to which they were, I believe, contributed by Mr. White of Glasnevin. The species are :—

Trifolium maritimum. Probably was *T. striatum.*
T. scabrum. I searched for this plant carefully without success.
Drosera rotundifolia.
Montia fontana. } Perhaps lost through drainage.
Senecio aquaticus.
Œnanthe peucedanifolia. Perhaps *Œ. lachenalii,* which is, however, also mentioned; and
Sambucus ebulus, which is not there now.

XCI.—Report on the Flora of the Mountains of Mayo and Galway. By H. C. Hart, B. A.

[Read, January 22, 1883.]

Having received a grant from the Royal Irish Academy for the purpose of continuing my examination of the Botany of the Irish mountains in 1882, I resolved to devote my exertions to those situate in Mayo and Galway. In a little less than a month, during two visits in June and July, I traversed all the mountains of important height—about 2000 feet and upwards. Some were so utterly barren that a single visit sufficed. I have, however, taken each chain separately in my report and dealt with its peculiarities, and will, therefore, merely enumerate them here, starting at the north-east. The figures are the height in feet, from the Ordnance Map.

In Mayo:—

Nephin, 2646.
Knockaffertagh, 1695; Birreencorragh, 2295; and Buckoogh, 1935.
Laghtdauhybaun, 2369; Corslieve, 1785; Nephinbeg, 2065; Glenamorig, 2067; and others of the range.
Curraun Achill, 1784 and 1715.
Achill, 2204 and 2192.
Croaghpatrick, 2510.
Mweelrea group; Delphi Mt. 2504 and 2474; Ben Gorm and Ben Cregan, 2383 and 2283; and Mweelrea, 2688 and 2610.

In Mayo and Galway:—

Slieve Partry or Maamtrasna group; Devilsmother, 2131; Maamtrasna (Formnamore), 2239 and 2209.

In Galway:—

Maamturk range; Leckavrea, 2012; Corcogemore, 2045; Maumeen, 2076, &c.; Letterbrickaun, 2195; Maamturkmore, 2300; and others of the chain.
Benchoona, 1975.
Bennabeola or Twelve Bens; Benbaun, 2395; Ben Lettery, 1904; Muckanaght, 2153, &c.

A short sketch of the botany of each of these groups will be given, and finally a general view of the vertical range of plants throughout the Mayo and Galway mountains. As heretofore, I refrain from comparing these results with those obtained in other parts of Ireland until the whole be completed.

A few general features may first be noticed. Cultivation is rarely seen on the mountains at any considerable elevation. The highest seen was on the south-eastern slopes of Birreencorragh, north of Newport, at 400 feet. Cultivated fields, grain, or tillage, scarcely extend above 200 feet in the neighbourhood of the higher mountains. Rye is a favourite crop in the west of Mayo. Potatoes depend mainly on a dry season during the first part of July: upon this the peasantry stake the success of their crop. There is little flax grown compared with Donegal, and wheat is rarely seen. The climate is milder than that of the east side of Ireland, and very much wetter. It is my belief that, if reliable records were taken, the neighbourhood of Delphi, at the base of Mweelrea and the upper part of Killary Fiord, would stand somewhere about the top of the list of rainfalls in the kingdom. In consequence of this mildness, especially in winter, and the shelter from the severity of easterly winds, the mountainous parts of the west have a far richer flora than those on the eastern side. On the other hand, several ranges in Galway are unusually barren from their geological nature. The absence of "mountain limestone" is prejudicial; and the prevalence of quartzite banishes many plants from large areas. On this rock, and the scanty soil it furnishes, only a few plants care to live. Of the mountain species, which sometimes appear quite at home on quartzite, the following may be mentioned:—

Silene maritima.	Armeria maritima.
Saxifraga umbrosa.	Salix herbacea.
S. stellaris.	Juniperus nana.
Antennaria dioica.	Carex rigida.
Arctostaphylos uva-ursi.	Lycopodium selago.
Empetrum nigrum.	L. alpinum

The other alpine species must be sought for off the quartzite, and where this rock is flanked by schists, &c., the line of demarcation of the alpine plants is, where they occur, rigorously defined.

None of the above are confined to the quartzite; they grow as freely on sandstone, granite, or other siliceous rocks, and some of them on all sorts of rock; but they may be regarded as almost its only alpine or sub-alpine inhabitants. As a rule, these mountains present wide surfaces devoid of all vegetation, the different species of heather appearing only in patches.

Under Croaghpatrick and The Twelve Bens will be found described my most interesting discoveries; a separate list of these will presently be given. New localities were found for all the alpine species recorded from the mountains of Mayo and Galway (District 8 of the "Cybele Hibernica"), and several more were added to the list. These plants descend to an unexpectedly low level, especially in Galway. There is little use in comparing these two counties, since the

mountains are almost continuous. The real difference lies north and south of Clew Bay. South of this bay, which is continuous with low levels inland, alpine species are more numerous and descend lower, and this is still further the case south of the Killary in the Connemara district. In one sense this is more an apparent than a real difference, since the most universal species, *Salix herbacea* and *Carex rigida*, are scarcer in quantity southwards: the variety of kinds is, however, greater and wider-spread. *Carex rigida* descends to an unusually low level at Nephin Beg—the lowest, I think, recorded. *Aira cæspitosa*, var. *alpina*, was only met with on the Mayo mountains, or on the bordering chain.

Of those more thoroughly alpine plants which never descend to sea level in these mountains (or elsewhere in Ireland), only three are ever met with on the exposed summits or outer ridges; these are: *Salix herbacea*, *Carex rigida*, and *Lycopodium alpinum*. As soon, however, as the ground contours downwards towards any part of the horizon, except north or north-east, these disappear. On the northern faces of cliffs these are, as a rule, confined to a higher zone than the other alpine plants, especially *Lycopodium alpinum*, which rarely leaves the flatter summits and shoulders. Of those which do not descend to, or nearly to, sea level, *Saxifraga oppositifolia* has the lowest range. Croaghpatrick, Maumeen, Ben Lettery, and Muckanaght, best illustrate the alpine flora of the Mayo and Galway mountains.

On Muckanaght, in The Twelve Bens, I found a Saxifrage which is, as far as I can make out, indistinguishable from *S. cæspitosa* (Linn.) Mr. Baker, who has kindly examined it, has, I am happy to say, confirmed my opinion. I have compared specimens with some brought home from Greenland in 1876, and except for a more stunted habit in the northern plants, there appeared no difference.

S. cæspitosa (Linn.) has rested hitherto as an Irish plant upon the evidence of an imperfect specimen from Brandon, gathered in 1829.[1] No form of *S. hypnoides* has been previously discovered in the Mayo or Galway mountains. Some plants at the lower part of its range on Muckanaght approach so closely to *S. platypetala*, especially to the form on the Galtee mountains, that my belief was confirmed that these forms are inseparable to a degree worthy of specific rank. Higher up on the cliffs the Muckanaght Saxifrage is fairly typical *S. cæspitosa*. Any stunted flowering stems of *S. affinis* or *S. hirta* which I have met with elsewhere in Ireland have several leaves on the stem. The Connemara plant has only one, or in rare instances, two. This is an important character, and also separates and is distinctive of the larger and somewhat straggling plant at the base of the mountain from *S. platypetala*. The flowers in the Connemara plant are fewer, usually one to three, and even in the larger forms nearly sessile; in *S. platypetala* they are

[1] A. G. More—"Recent Additions to the Flora of Ireland."

pedicelled to half an inch or more. The leaves and sepals are much blunter than in any other Irish Saxifrages of the race, and the ovaries more distinctly semi-included in the calyx, which points to another character in the sepals being shorter: these latter are studded with gland-tipped hairs. The petals are also smaller in proportion to the sepals. The Connemara plant has not the weak trailing shoots of most of the *S. hypnoides* forms, and is, generally speaking, more distinct than any of them; widely so from the extreme plant *S. sponheimica*, which mainly differs from *S. hypnoides* in the absence of bulbs in the leaf axils.

In my Report on the Macgillicuddy's Reeks I have noticed the distribution of this race of plants upon some of the Kerry mountains, and on the Galtees in Tipperary. I have this year visited Ben Evenagh in Derry, and the Cummeragh and Knockmealdown mountains in Waterford. *S. sponheimica* (Gm.) is the plant which grows on these, its typical form occurring on the Derry basalt.

With regard to the Hieracia, to which I also paid particular attention, the following forms were gathered:—

Hieracium anglicum (Fr.) }	H. vulgatum (Fr.) }
H. iricum (Fr.) }	H. gothicum (Fr.) }

H. anglicum occurs frequently on the mountains as an alpine plant, and rarely at low levels in exposed rocky places. *H. iricum*, in its large, much-branched, very leafy form, is a plant of the glens and intermediate stations, never occurring in alpine situations. It passes into *H. anglicum* in intermediate stations, as above Doo Lough, opposite Delphi, and on Benchoona, in a series of doubtful plants; and having gathered a number of specimens throughout the two counties, I feel convinced that *H. iricum* is merely a luxuriant lowland form of *H. anglicum*. Typical *H. iricum* is rare in Ireland; it occurs in Galway at Kylemore and Benchoona. The Galtee form of *H. anglicum*, as well as that gathered on the Reeks, is intermediate, while the commonest hawkweed in mountainous districts of Donegal is typical *H. anglicum*.

H. vulgatum is scarce, and I only met with it on Muckanaght, where it passes insensibly into *H. gothicum*, which is, perhaps, the alpine form; it does not, however, occur with the alpine species. Typical *H. gothicum* is best seen at Maumeen, amongst the alpine plants. I met with neither of these in Kerry; but both occur, with intermediate forms, in Innishowen, Co. Donegal.

The vertical range of *Saxifraga umbrosa* calls for a note. In Kerry it descends from the highest summits to sea level or low levels inland constantly in the mountainous regions; in the Galtee, Cummeragh, and Knockmealdown mountains, it is thoroughly alpine in its general elevation, and though not dependent on aspect as alpine plants usually are, it never descends lower than 1700 or 1800 feet. In the Mayo and Galway mountains *Saxifraga umbrosa* occasionally

descends to sea level on the coast, usually ceasing at about 700 to 1000 feet and upwards. In Donegal it rarely descends lower than about 2000 feet. Its general range is thus diametrically opposite to that of the alpine group, and is more properly classed with the Atlantic or Western type.

Lest it should be thought that I have crowded in notes of heights at random, I would ask leave to give the motives which usually guided me in making the records. They are either to ascertain—

1. Upper and lower limits of alpine plants.
2. Upper limits of all species occurring on the mountains.
3. Unusually high or low elevation for any plants, outside their apparent normal limits.
4. Notes on rare, local, or characteristic species.
5. Repeated observations on plants whose range will apparently prove to be very constant, and, therefore, important to ascertain accurately.

Having seen, moreover, how erroneous estimates of vertical ranges are, unless taken from a wide series of observations, I have slight scruples in recording what may appear to be an excess. An additional reason may be given in the obvious one that inaccuracies arising from a variable condition in the barometer, while observations are being made, will be reduced and equalized by considering the average of many records. By this means I have generally arrived at a very close approximation to the truth with regard to the altitude of certain lakes. The upper limits of some mountain plants are as definitely fixed as the mountains themselves.

The mountainous district examined contained 227 species above the elevation of 250 feet. A few of these are, however, merely varieties. The district is included in district 8 of the "Cybele Hibernica."

The following belong to Watson's Highland or alpine tpye:—

Thalictrum alpinum.
Sedum rhodiola.
Saxifraga stellaris.
S. cæspitosa.
S. oppositifolia.
Saussurea alpina.
Hieracium anglicum et H. iricum.
(H. gothicum.)
Arbutus uva-ursi.
Vaccinium vitis-idæa.
Oxyria reniformis.
Salix herbacea.
Juniperus nana.
Carex rigida.
Polystichum lonchitis.
Aira alpina.
Asplenium viride.
Lycopodium alpinum.
L. selaginoides.
Isoetes lacustris.

In addition to these, *Dryas octopetala*, *Galium boreale*, *Hieracium crocatum*, and *Sesleria cærulea*, are alpine plants occurring only at low levels elsewhere in District 8, as recorded in the "Cybele Hibernica." In the above list *Saxifraga cæspitosa*, *Saussurea alpina*, *Aira alpina*, and *Polystichum lonchitis* are additions to the flora of this district.

The whole is about two-thirds of the alpine flora of Ireland. Alpine varieties of *Armeria maritima, Alchemilla vulgaris, Plantago maritima, P. lanceolata,* and *Silene maritima* also occur.

The Scottish or northern group is well represented.

Thalictrum minus.	Pinguicula vulgaris.
Subularia aquatica.	Empetrum nigrum.
Drosera anglica.	Salix phylicifolia.
Sagina subulata.	Listera cordata.
Rubus saxatilis.	Habenaria albida.
Crepis paludosa.	Eriocaulon septangulare.
Antennaria dioica.	Carex limosa.
Lobelia dortmanna.	C. filiformis.

Several others occur in other parts of the district at low levels, as may be seen in the "Cybele Hibernica." Of the above, *Salix phylicifolia* is an addition to the Flora of district 8. Somewhat more than half the total number of the group occurring in Ireland are met with in the west of Mayo and Galway.

Of Watson's Atlantic type, the following plants occur on the sides of the mountains, mostly at low levels:—

Meconopsis cambrica,	Scirpus savii,
Sedum anglicum,	Lastrea æmula,
Cotyledon umbilicus,	Adiantum capillus-veneris,
Rubia peregrina,	Hymenophyllum tunbridgense,
Hypericum androsæmum,	H. wilsoni,
H. elodes,	
Pinguicula lusitanica,	

and several others along the coast.

Several other prevalent species in the west would advantageously be included in this group, to which their distribution in Ireland apparently refers them.

Since my general list is arranged with a view to exhibiting the vertical ranges, it is out of all systematic order, and it becomes difficult to refer to it for localities for the rarer species. I will therefore enumerate the rarest discoveries made, several of these being found in the lowlands during my excursions from one chain to another. Those italicized are additions to the flora of District 8 of the "Cybele Hibernica" and to Mr. More's supplement.

Thalictrum alpinum (Linn.)—Croaghpatrick, Ben Choona, Maam Turk (Maumeen), Muckanaght and Ben Lettery. Recorded by Wade from Lettery, and by Dr. Moore from the "mountain above Kylemore castle," a hill which I omitted to visit.

T. minus (Linn.), var. montanum, (Wallr.)—Mweelrea, and Ben Choona. Chiefly known previously on the stony shores of the larger lakes.

Meconopsis cambrica (Vig.)—Muckanaght in Bennabeola. Found previously near Clifden.

Arabis hirsuta (R. Br.) Maumeen.—Rare in the west, except on limestone.

‡Senebiera didyma (Pers.)—Achill sound at the ferry; a north-western limit for this spreading species, which had not previously been known north of Galway on this side of Ireland.

Rubus saxatilis (Linn.)—Mweelrea, Croaghpatrick, and Bennabeola.

Saxifraga cæspitosa (Linn.)—Muckanaght.

Saxifraga oppositifolia (Linn.)—Mweelrea and Muckanaght. Also on Maam Turk and Ben Lettery, which are given in the "Cybele" and one locality I did not verify, "mountains in Joyce country, near Lough Corrib."

Ægopodium podagraria (Linn.)—Near Westport.

Œnanthe lachenalii (Gmel.)—Near Bundorragha on the Killary. Known previously from one locality near Galway.

Œ. crocata (Linn.)—In several places about the Killary. Recorded only from Belmullet in the district.

Pastinaca sativa (Linn.)—Roadsides, and banks about Newport.

Rubia peregrina (Linn.)—Mweelrea and Salrock. Recorded previously from the shores of Lough Mask.

Saussurea alpina (Dl.)—Croaghpatrick, Ben Lettery, and Muckanaght.

Hieracium anglicum and H. iricum (Fr.)—Mweelrea and Ben Choona. H. anglicum is not unfrequent.

H. vulgatum (Fr.)—Muckanaght.

Arctostaphylos uva-ursi (Spr.)—Mweelrea, Nephin, and Nephinbeg in Mayo. More frequent in Galway.

Vaccinum vitis-idæa (Linn.)—Only met with in very small quantity in one place on Mweelrea. Other localities are given in the "Cybele" which I failed to verify. It is very rare in the west.

Scrophularia aquatica (Linn.)—Bundorragha, at the foot of Mweelrea; not seen elsewhere in the district except in the "Cybele" locality to the west of Galway.

Utricularia intermedia (Hayne.)—Frequent in the Mweelrea district at low levels, as well as about Connemara. This plant forms hybernacula, and if the fragile stem be lifted gently and traced through the mud with the fingers for the root, a little tuberous formation about the size of a bean will usually be found at the end of the stem. This habit is not mentioned in the British text-books, but Mr. Baker informs me that there are specimens exhibiting these hybernacula at Kew. I have seen undeveloped leaf-buds of U. vulgaris at the end of the summer, although not so dense; and Darwin says these "fall off and lie dormant during the winter at the bottom." In U. intermedia they remain attached, and form the point at which the arrested growth recommences the following season. Such a means of living is the more necessary to the present species, since it rarely seeds itself.

Statice bahusiensis (Frie.)—Shore below Croaghpatrick. Not found north of Clifden previously on the west side of Ireland.

Oxyria reniformis (Hook.)—On Loughty Mt. and Ben Gorm in the Mweelrea group, as well as on Mweelrea; not found on Ben Lettery, but grows on Muckanaght in Bennabeola; plentiful on Croaghpatrick.

Salix phylicifolia (Linn.)—By the stream out of Lake Lugaloughawn on Mweelrea. Mr. More agrees with me in this decision. A small, but handsome shrub with a distinct appearance, due to the somewhat shiny leaves, glaucous beneath, and rich-coloured twigs. Found in Ireland previously in two localities, one in Antrim and the other in Derry.

Salix herbacea (Linn.)—On all the higher mountains in both counties. Recorded only from Nephin and Nephinbeg.

Habenaria albida (Rich.)—Glen Laur. Also west of Galway and Lough Mask, "Cybele Hibernica."

Listera cordata (R. Br.)—Corcogemore. Recorded also from Slieve Cor.

Eriocaulon septangulare (With.)—Lakes west of Deel Bridge, between that and Corslieve. This extends the line marking its range on the map in the "Cybele Hibernica" northwards in Mayo to about the latitude of Crossmolina.

Sparganium natans (Linn.)—In a lake on the seaside of the road about half way between Newport and Molranny; in bog-holes about a mile south of Achill ferry on the mainland; at the foot of Croaghpatrick, on the inland side of the road by Clew Bay. In several places in Connemara.

S. minimum (Fr.)—Lake on Maamtrasna; Nambrackheagh lake on Buckoogh. Lake Lugaloughaun on Mweelrea.

Ruppia maritima (Linn.)—In a brackish pond near Newport.

Carex vulpina (Linn.)—With the last.

C. teretiuscula (Good)—By a lake about a mile from Newport on the roadside to Westport.

C. rigida (Good)—On all the higher Mayo mountains except Croaghpatrick. Only recorded from Nephin.

C. pallescens (Lam.)—Bennabeola, Mweelrea, and Delphi. It was perhaps this plant which Wade recorded as C. curta from Ben Lettery.

C. limosa (Linn.)—In a very wet bog at the foot of Nephin between Crampaun river and the road; southern side of Birreencorragh by some small lakes; bog-holes by the roadside between Ballinahinch lake and the canal bridge; bog-holes near Lough Fee to its east and between that and the Killary; at the base of Derryclare mountain by the shore of the lake.

C. filiformis (Linn).—In all the bogs with the last species, except the last-mentioned one. Also by the Erriff at the base of Ben Gorm. These two species occur in the very wettest shaky bogs in places which are usually considered unsafe to tread on. They have been recorded from only one or two localities in the west.

Lastræa oreopteris (Presl.)—Rather rare in the west. Letterbrickaun valley and Glencroff near the Killary.

Polystichum lonchitis (Roth.)—Muckanaght—only locality.

P. aculeatum (Roth.), Var. lobatum—Muckanaght and Maumeen.

Cystopteris fragilis (Bernh.)—Loughty Mt.; Muckanaght and Maumeen. Very rare.

Asplenium viride (Huds.)—Muckanaght; Croaghpatrick and Ben Lettery. Only recorded from the last locality before.

Adiantum capillus-veneris (Linn.)—Achill (and Salrock?). Very rare, but recorded from one or two localities previously.

Lycopodium clavatum (Linn.)—On the mountain opposite Leenane Hotel on the Killary. Appears to be very scarce, but I was not much on the lower grassy hills which this species affects.

L. alpinum (Linn.)—Mweelrea; Loughty Mt.; Curraun Achill, and Maam Turk. Recorded from the last locality and Ben Lettery, where I did not observe it.

Before proceeding to my detailed account of the mountain ranges, I take this opportunity of expressing my thanks to Professor Babington of Cambridge, Mr. Baker of Kew, and Mr. More of Dublin, who have kindly examined and given their opinion upon rarer and critical species.

In my survey of each mountain, I suppose the reader to start from the summit and descend downwards in various directions.

Nephin is an isolated, rounded lump of quartzite, rising to 2646 feet above sea level. It is second in height to Mweelrea in Mayo, the highest in the west of Ireland, and situate north-west of Newport on Clew Bay. The barren nature of the rock of which it is formed, and the even shape of its surface, render it obviously uninteresting botanically. Nevertheless it appears to be the only point in the west which has received much attention from botanists, and these reasons, combined with a steady downpour of rain, caused me to be satisfied with a rather hurried survey. Dr. Dickie has given a slight account of its plants in his "Flora of Ulster." He records *Carex rigida* from the summit, 140 feet higher than I observed it, and three common species which I noticed on the top do not appear in his list. There is, however, a stranger disagreement between us. *Arctostaphylos uva-ursi* is very abundant south from the summit in the direction of Crampaun Wood. It appears, as we descend, at about 1650 feet; is very abundant at 1500, and disappears at about 1240. Neither Dr. Dickie nor Professor Babington observed this species, although both have recorded *Vaccinium vitis-idæa* from Nephin, which I did not meet with. The former does not, however, include it in the list of Nephin plants given in his Introduction. *Vaccinium vitis-idæa* appeared to me extremely rare in Mayo and Galway; at least, on the higher mountains. Dr. Dickie does not mention *Antennaria dioica, Hieracium anglicum, Salix herbacea, Silene maritima,* or *Saxifraga stellaris,* which I met with at considerable heights.

On the north-eastern side of the northern spur of Nephin, the rock

is more schistose in its nature, and on some slight prominences in a steep and rapidly degrading declivity, a few alpine plants occur. Here, as on Croaghpatrick in a less striking manner, one cannot fail to be impressed with the idea how insecurely established these slight patches of rarer plants on a continually wearing surface must be; how many may have disappeared, or are gradually disappearing, except on those mountain ranges where solid ranges of cliffs occur. This crumbling schistose rock is, in Mayo and Galway, the chief home of the alpine plants, overlying the prevalent quartzite formation in detached positions, and forming a rich and suitable soil by its rapid disintegration. Its scattered and infrequent occurrence, as well as its unstable nature, may, in some degree, account for the unsatisfactory, casual distribution of the alpine flora.

At the base of Nephin, on the south-western side, there is a considerable patch remaining of an ancient forest. During my visit to this part of Mayo I lodged with a kindly and respectable "strong" farmer named Daly, who has lived here for seventy years, and whose forefathers held the ground before him. He remembers when, instead of a strip a couple of miles long, there were many square miles of forest, which, in his father's time, clothed the long valley northward towards Deal Bridge; when the bitterns, "like bulls," answered one another over the moors. He had seen ruffs here in his youth, a pair of which had been shot about forty years ago, and the *mad-ye-'eran* (pine-marten) was then frequent in the forest. There was also "a wild cat which dogs that would face a fox would not cope with." I was specially interested in his account of squirrels having formerly been frequent in these native woods, which, if true, would surely establish its claim to being an indigenous inhabitant animal of Ireland. My informant was very intelligent and apparently, as well as by reputation, quite trustworthy. At the mention of squirrels, I asked him to describe them, which he did, and their "drays," as he had seen them in these woods, quite correctly. He says they are still there in much diminished numbers, living, as of old, on the nuts which abound there. These remarks may savour to some more of romance than of scientific research, and must, no doubt, be received with caution; but the question whether the squirrel is indigenous or not in Ireland has been the subject of much careful investigation by my friend Mr. Barrington, who has, in an able Paper on the subject, decided against it. The above clue, if worked out, may throw new light on the question.

The mention of the forest led me to the above digression. I examined these woods carefully, and found the following trees to be indigenous:—ash, oak, birch, mountain ash, alder, sallow (*Salix caprœa*), hazel, and blackthorn. Some of the alders are remarkably well grown —forty to fifty feet high—with a trunk over a foot in diameter; the ash trees are of medium size; the oaks old, but badly developed.

The alpine plants I observed on Nephin were—*Saxifraga stellaris*, *Hieracium anglicum*, *Arctostaphylos uva-ursi*, *Salix herbacea* and

Carex rigida. *Saxifraga umbrosa* is abundant from the base to the summit.

NEPHIN SUMMIT.

2640 feet.

Potentilla tormentilla.	Rumex acetosa.
Saxifraga umbrosa.	Luzula sylvatica.
Galium saxatile.	Anthoxanthum odoratum.
Calluna vulgaris.	Aira flexuosa.
Vaccinium myrtillus.	Festuca ovina.
Empetrum nigrum.	Asplenium dilatatum.
Armeria maritima.	Lycopodium selago.

NORTH-EAST SLOPE.

2500 feet.

Carex rigida.

2450 feet.

Saxifraga stellaris. | Salix herbacea.

NORTH-WEST SLOPE.

2300 feet.

Melampyrum montanum.

SOUTH SPUR.

1830 feet.

Salix herbacea (lower limit). | Antennaria dioica.

1870 feet.

Silene maritima.

1750 feet.

Erica cinerea.

1660 feet.

Arctostaphylos uva-ursi.

1490 feet.

Hieracium anglicum.

WESTERN SLOPE.

1290 feet.

Solidago virgaurea. | Erica tetralix (upper limit).

Hymenophyllum unilaterale.

WESTERN SLOPE—*continued.*

1240 feet.

Antennaria dioica, Lycopodium selago } Scarce. | Arctostaphylos uva-ursi (lower limit).

1000 feet.

Empetrum nigrum (lower limit).

700 feet.

Comarum palustre. | Lychnis flos-cuculi.

500 feet.

Cratdegus oxyacantha. | Drosera anglica.
D. rotundifolia.

250 feet.

Sanicula europæa. | Lastrœa œmula.
Ilex aquifolium. | Osmunda regalis.

In Crampaum woods few plants of interest were observed, the trees have been already mentioned. Along the mountain's western base were noted *Bidens cernua, Crepis paludosa, Pinguicula lusitanica, Hypericum androsæmum, Scirpus setaceus, S. savii, Habenaria chlorantha, H. bifolia, Plantago maritima* (low inland level), *Festuca sciuroides, Carex pulicaris, C. sylvatica,* and other commoner sedges; while to the west of the road, in a very wet bog between it and Crampaun river, I observed *Utricularia minor, U. intermedia, Drosera intermedia, Allium ursinum* (by the river), *Schœnus nigricans, Rhynchospora alba, Carex paniculata, C. ovalis, C. limosa,* and *C. filiformis.* These two last rare species I have several times noted together in the wettest spongy bogs in Mayo and Galway.

A few miles westward of Nephin, across the valley of the Crampaun river, lies a cluster of mountains around the head of the Skirdagh river, of which the highest are Birreencorragh, 2295 feet, and Buckoogh, 1900 feet above Lough Feeagh, which is almost an estuary from Clew Bay. These are uninteresting mountains, devoid of cliffs, and unsuitable for genuine alpine plants, none of which were met with. A series of notes on the upper ranges of lowland species was made, however, and a few interesting mountain plants are recorded. On the south-eastern slopes of Birreencorragh there are cultivated fields to about 400 feet; the highest I met with in the west.

BIRREENCORRAGH, SOUTH SIDE.

2000 feet.

Silene maritima. | Armeria maritima.

BIRREENCORRAGH, SOUTH SIDE—*continued.*

1500 feet.

Erica cinerea (appears).

1200 feet.

Erica tetralix (appears).

1150 feet.

Antennaria dioica. | Narthecium ossifragum.
Lycopodium selago.

HEAD OF THE SKIRDAGH RIVER.

1100 feet.

Linum catharticum. | Carduus pratensis.
Bellis perennis. | Prunella vulgaris.
Holcus lanatus.

900 feet.

Carex fulva.

775 feet.

Alchemilla arvensis. | Myrica gale.

600 feet.

Eleocharis multicaulis. | Pteris aquilina (appears).

SOUTH-EASTERN SLOPES, TOWARDS DERRYROE BRIDGE.

380 feet.

Anthemis chamomilla. | Agrostis pumila.

350 feet.

Nymphœa alba. | Eriocaulon septangulare.
Hypericum elodes. | Scirpus fluitans.
Lobelia dortmanna. | Rhynchospora alba.
Utricularia intermedia. | Carex limosa.
Menyanthes trifoliata. | C. filiformis.

BUCKOOGH.

1920 feet.

First six of Nephin, and | Juncus squarrosus.
Solidago virgaurea. | J. effusus.
Pinguicula vulgaris. | Eriophorum polystachyon.
Luzula sylvatica. | Scirpus cæspitosus.
L. campestris. | Festuca ovina.
Aira flexuosa.

EAST SIDE.

1880 feet.

Scabiosa succisa.

1680 feet.

Oxalis acetosella.

LAKE NAMBRACKKEAGH.

1180 feet.

Trifolium repens.	Salix aurita.
Lysimachia nemorum.	Potamogeton natans.
Lobelia dortmanna.	Sparganium minimum.
Litorella lacustris.	Carex vulgaris.

Isoetes lacustris.

To the west of this cluster of mountains a long valley runs north from Lough Feeagh, along the eastern flanks of the Nephinbeg range, till it meets the great moorland west of Crossmolina, through which the Deel river runs. About ten miles north of Lough Feeagh, near Deel Bridge, there is a multitude of small lakes on this wet moor, in which I found *Eriocaulon septangulare*, a station somewhat north of the line marking its range in Mayo, as given in the "Cybele Hibernica." Mamm-y-Kelly, 1205 feet, rises from this moorland, and forms the northern extremity of the Corslieve range, which is continuous in direction, and forms one with the Nephinbeg range. They are, however, severed by a low valley, 750 feet, between Corslieve and Nephinbeg, and there is a still lower one between Nephinbeg and Glenamorig. The whole chain runs about fifteen miles southwards to the waters of Clew Bay. Much of it is over 2000 feet above sea level, and it rises to nearly 2400 feet in two or three points. These mountains are chiefly quartzite, of the barrenest description, and contain a poor flora. *Salix herbacea* and *Carex rigida*, two of the few plants which thrive on this formation, are, however, very abundant. These and *Arctostaphylos uva-ursi* were the only Alpines met with; the occurrence of *Carex rigida* at so low a level as 860 feet is very remarkable. I walked this range from north to south, leaving my car about two miles north of Deel Bridge, and finishing the same night at Newport. This was intended to be a preparatory exploration; but these mountains appeared utterly unworthy of a second botanical visit. They are wild and grand and rugged enough, with many a bit of lovely scenery, as about Scardaun Lake; but one gets to know the capabilities of mountains for containing varieties, and the few likely places at sufficient altitude were searched with very slight success. The highest point of the Corslieve group is called "Laghtdauhybaun" on the map. I did not hear this "jaw-breaker" used in the country, and I may be excused if I call it all Corslieve.

Corslieve, down to North-east.

2320 feet.

Saxifraga umbrosa. | Salix herbacea.
Carex rigida.

2250 feet.

Melampyrum montanum. | Empetrum nigrum.

2025 feet.

Carex rigida. | C. pilulifera.
C. binervis.

1750 feet.

Hymenophyllum unilaterale.

1700 feet.

Pyrus aucuparia.

Lake Drumderg.

1330 feet.

Saxifraga umbrosa. | Isoetes lacustris.

600 feet.

Epilobium obscurum. | Pinguicula lusitanica.
Equisetum sylvaticum.

Wet Moor at 250 feet.

Lychnis flos-cuculi (white). | Eriocaulon septangulare.
Lobelia dortmanna. | Rhynchospora alba.
Utricularia minor. | Eleocharis multicaulis.

Down South towards Scardaun Lake.

2000 feet.

Saxifraga stellaris. | Oxalis acetosella.
Carex rigida.

1700 feet.

Crepis paludosa.

1600 feet.

Sedum rhodiola.

1400 feet.

Saxifraga stellaris.

SCARDAUN LAKE, N.-E. CORNER.

860 feet.

Lobelia dortmanna. | Narthecium ossifraga.
Iris pseudacorus. | Carex rigida (lower limit).
Isoetes lacustris.

NEPHINBEG.

2060 to 1900 feet.

Carex rigida.

SOUTH SIDE.

1425 feet.

Erica cinerea.

1325 feet.

Holcus lanatus.

850 feet.

Eleocharis multicaulis.

GLANAMORIG, DOWN N.-W.

2100 feet.

Salix herbacea. | Carex rigida.

1750 feet.

Narthecium ossifragum.

1700 feet.

Salix herbacea (lower limit).

1600 feet.

Carex rigida (lower limit).

400 feet.

Hymenophyllum tunbridgense.

325 feet.

Antennaria dioica. | Arctostaphylos uva-ursi.

RIDGE SOUTH OF GLENAMORIG.

2300 to 1750 feet.

Carex rigida (abundant).

2200 feet.

Poa annua.

Westwards of this chain of mountains the land subsides to lower levels along Blacksod Bay and Bellacragher (Ballycroy) Bay. The latter winding, narrow estuary, runs down from the northwards to within an English mile of Clew Bay on the south. This peninsula, about six or seven miles in diameter, is called Curraun Achill, and is separated by the narrow strait of Achill Sound from Achill Island. Curraun Achill is known to botanists as being the head-quarters of the Mediterranean heath in Ireland. It is all mountainous: consisting of a detached peak (1500 feet) in the northern part, which I did not examine, and a wide table-land at about 1300 feet, rising in places to 1700 feet, above sea level, which includes the chief southern part of the promontory. This table-land is composed of quartzite, and subsequently of horizontally stratified sandstones and conglomerates, which break away into regular terraces along its north-eastern edge of a picturesque and unusual character. This sandstone is, I believe, lower carboniferous; it soon, however, gives place to the perpetual quartzite forming the greater part of Curraun. On the table-land, at 1200 feet, Arctostaphylos, Empetrum, and Juniper form a carpet, the first and last being remarkably abundant. At a greater height *Salix herbacea* and *Carex rigida* were, as usual, met with, and with these a rarer alpine species, *Lycopodium alpinum*, which was only seen in two or three places in the west.

CURRAUN ACHILL, DOWN NORTH-EAST.

1560 feet.

Salix herbacea.	Carex flava.

Lycopodium alpinum.

1200 feet.

Lotus corniculatus.	Plantago maritima.
Arctostaphylos uva-ursi.	Empetrum nigrum.
Armeria maritima.	Juniperus nana.

200 feet.

Hymenophyllum tunbridgense.	H. unilaterale.

150 feet.

Erica mediterranea.

SOUTH OF FERRY, NEAR SEA LEVEL.

Sparganium natans.	Rhynchospora alba.

The Island of Achill is shaped somewhat as a right-angled triangle, the shorter sides running due north and south, east and west. From

the north-east corner it is about fifteen miles to Achill Head, the western extremity, and about the same distance along Achill Sound to Achill Beg Island on the extreme south. The base line from north-west to south-east is curved far inwards, and the whole coast line thoroughly "nook-shotten." The ferry by which the island is reached lies about the middle of the eastern side of the island. It is hardly a stone's throw across, and fordable at low water. From this point to the missionary settlement on the northern coast of the island is about ten miles, where comfortable quarters are available at Mr. Sheridan's hotel, whose enthusiastic love for natural history, and ability and willingness to act as guide, add to the interest of a visit. The settlement is situated at the eastern base of Slieve More, 2204 feet, the highest point of Achill. This mountain slopes gradually to the sea. Soon, however, the coast line rises again, becoming more and more precipitous, till it finally culminates in the noble range of cliffs at Croghaun, 2192 feet, about five miles west of Slieve More. A day along these higher parts of Achill gave the undermentioned results. The formation is quartzite chiefly, and the flora appears uninteresting. I searched several likely places for the more remarkable west of Ireland plants; but, with the exception of London Pride and Maiden Hair fern, none were met with. The discovery of the latter is not due to me; but it has not, I think, been previously recorded. As I had expected, the alpine sedge and willow, so prevalent in the west, occur at suitable heights on the quartzite of Achill.

Slieve More (down East and North-East).

2200 feet.

Oxalis acetosella.	Armeria maritima.
Vaccinium myrtillus.	Empetrum nigrum.

Plantago maritima, &c.

2080 feet.

Saxifraga stellaris.

2030 feet (and upwards).

Salix herbacea	Carex rigida

1730 feet.

Saxifraga umbrosa (and upwards).	Solidago virgaurea.
	Luzula sylvatica.
Melampyrum pratense.	Carex flava.

Hymenophyllum unilaterale.

1430 feet.

Pyrus aucuparia.	Hieracium anglicum.
Sedum rhodiola.	Asplenium trichomanes.

Hymenophyllum tunbridgense.

At or near Sea Level.

Sedum rhodiola.	Empetrum nigrum.
Samolus valerandi.	Salix repens.
Pinguicula vulgaris.	Scirpus savii.
P. lusitanica.	Kœleria cristata.

Croghaun.

1900 feet.

Oxalis acetosella.	Lastrœa dilatata.
Salix herbacea.	Hymenophyllum wilsoni.

North Face.

1825 feet.

Saxifraga stellaris.	Carex rigida.

East Side.

1480 feet.

Polygala depressa.	Narthecium ossifragum.
Pinguicula vulgaris.	Juncus effusus.

South Side.

1300 feet.

Arctostaphylos uva-ursi. } Scarce.
Juniperus nana. }

East Side.

800 feet.

Pinguicula lusitanica.

800 feet.

Sedum anglicum.

Near Sea Level.

Adiantum capillus-veneris.

At the ferry at Achill I observed *Senebiera didyma*—the most northern point it seems to have spread to on the west of Ireland. Near Newport, by the roadsides and elsewhere, were observed *Eupatorium cannabinum*, *Pastinaca sativa*, *Carex teretiuscula*, and *Juncus glaucus;* and in a brackish pond, *Carex vulpina* and *Ruppia maritima*. None of these last, except Eupatorium, which appeared to me very rare in the western mountainous districts, are recorded in the "Cybele Hibernica" from District 8. Between Newport and Mulranny I saw

Apium graveolens, Bidens cernua, B. tripartita, Scirpus tabernæmontani, and *Sparganium natans,* the latter being especially plentiful in a pond about half way on the seaward side of the road. A willow, apparently *Salix purpurea,* in wet hedges along the roadside between Newport and Westport, may be worth examining when in flower, but it is probably planted.

The mountains of Mayo considered so far lie to the north of Clew Bay. I shall now describe the vegetation of those situated in the southern part of the county. There is a considerable increase in the variety of species to be met with both of lowland and mountain plants, as compared with the barren district we are leaving behind. There is also, fortunately, a considerable increase in the accommodation to be met with; and, although there are no more maritime cliffs akin in grandeur to those of Achill, there is far more loveliness of lake and mountain scenery, ever increasing as we travel south to Connemara. The most conspicuous feature on the southern side of Clew Bay, perhaps in the whole west of Ireland, is Croaghpatrick, 2510 feet. This mountain is easy of access from Westport, there being, I believe, a bridle-path to the summit; and I had almost concluded, since no plants of interest have been accredited to it, that it had been long known to contain none, the more so since it appeared to be composed of the inevitable and inhospitable quartzite. The "Cybele Hibernica" has but two records from Croaghpatrick, *Silene maritima* and *Armeria maritima,* both unimportant. These are due to Dr. Patrick Browne. The mountain has therefore been botanized; and, since it is the Irish locality for the only Irish alpine butterfly, *Erebia cassiopeia,* as I am informed by Mr. More, it has by no means escaped the attention of naturalists. Fortunately, however, I determined to try for myself, and a fine northern face of precipitous declivities looked and proved to be worthy of a botanist's attention. Before describing the flora of Croaghpatrick, I must say one word for the view from the summit. It does not equal in grandeur that from Carran Tuohill, or in rugged wildness that from Slieve Snacht West in Donegal; but, as I think, no other point in Ireland, with its wide and varied prospect of lake and mountain, island and ocean, gives a scene of such surpassing loveliness as Croaghpatrick.

"The Reek," as this mountain was formerly called, sloping gradually to the water's edge as it does, is well suited for noticing the vertical range of plants. Greater accuracy with the aneroid was perhaps here arrived at than in the previous ranges, so that a more copious series of observations will be recorded. These were chiefly taken on the northern face, and on this face an interesting assemblage of alpine plants was discovered. These were: *Oxyria reniformis, Saussurea alpina, Thalictrum alpinum, Asplenium viride,* and *Salix herbacea,* as well as other commoner ones, all in plentiful quantity. *Saussurea alpina* has not been previously gathered in Mayo or Galway. *Thalictrum alpinum* and *Asplenium viride* only in a single locality each. *Carex rigida,* as is sometimes the case, is supplanted here by *Carex flava.*

The rock, or rather shingle, amongst which these plants grow is a rapidly disintegrating schistose rock. The slopes are very steep and of insecure footing, but with a little care all these plants may easily be viewed, and the risk is rather that of a slide upon gravel than a fall amongst cliffs.

CROAGHPATRICK.

Summit, 2510 feet.

The first twelve of NEPHIN and Rumex acetosella

Juncus squarrosus. | Poa annua.

DOWN SOUTH-EAST.

2350 feet.

Carex binervis.

1850 feet.

Eriophorum vaginatum.

1740 feet.

Juniperus nana. | Lycopodium selago.

1690 feet.

Erica cinerea (begins).

1670 feet.

Antennaria dioica.

DOWN NORTH.

1900 feet.

Viola sylvatica. | Jasione montana.
Melampyrum pratense.

1850 feet.

UPPER LIMIT OF ALPINE PLANTS.

Salix herbacea. | C. pilulifera.
Carex flava. | C. binervis.

1800 feet.

Asplenium viride.

1740 feet.

Sedum rhodiola. | Oxyria reniformis.
Hedera helix. | Blechnum boreale.
Euphrasia officinalis. | Asplenium viride.
Polypodium vulgare.

CROAGHPATRICK—*continued.*

1650 feet.

Cardamine hirsuta.	Taraxacum dens leonis.
Sagina procumbens.	Hieracium anglicum.
Rubus saxatilis.	Primula vulgaris.
Scabiosa succisa.	Carex panicea.

Lastrœa dilatata.

1630 feet.

Senecio jacobœa.	Rhinanthus crista-galli.
Hieracium anglicum.	Plantago lanceolata.

Lastrœa filix-mas (var. abbreviata).

1590 feet to 1570 feet.

Ranunculus repens.	Oxyria reniformis (lower limit).
Thalictrum alpinum.	Primula vulgaris.
Viola sylvatica.	Pinguicula vulgaris.
Polygala vulgaris.	Thymus serpyllum.
Oxalis acetosella.	Euphrasia officinalis.
Sedum rhodiola.	Salix herbacea (lower limit).
Angelica sylvestris.	Carex flava.
Saussurea alpina (lower limit).	Eriophorum polystachyon.
Crepis paludosa.	E. vaginatum.
Taraxacum densleonis.	Asplenium trichomanes.
Campanula rotundifolia.	

A. viride (lower limit).

1560 feet.

Erica cinerea (begins).

1390 feet.

Dabæocia polifolia.

1370 feet.

Ranunculus flammula.	Stellaria uliginosa.
Cardamine pratensis.	Cerastium triviale.
Viola palustris.	Myosotis repens.
Trifolium repens.	Callitriche platycarpa.

1300 feet.

Pteris aquilina.

1280 feet.

Digitalis purpurea.	Orchis maculata.

1170 feet.

Erica tetralix.

CROAGHPATRICK—*continued.*

1000 feet.

Solidago virgaurea.	Empetrum nigrum (lower limit).

820 feet.

Carduus palustris.	Anagallis tenella.

630 feet.

Cotyledon umbilicus.	Scilla nutans.
Pyrus aucuparia.	Lastræa æmula.

300 feet.

Ulex europaeus.

250 feet (Cultivation begins).

At sea level, at the base of Croaghpatrick, I noticed on the south side of the road in deep ditches by a pond *Alisma ranunculoides*, *Sparganium natans*, and *Carex paniculata*; and on the shore at the north side of the road, *Kœleria cristata*, *Carex extensa*, *C. distans*, and *Statice bahusiensis*, with commoner species. Statice has not been found north of Clifden on the west coast previously. On the way to Westport I noticed *Ægopodium podagraria*, not before recorded from western Mayo or Galway.

From the summit of Croaghpatrick, the most prominent group of mountains in view is that of Mweelrea, about eight or ten miles distant in a south-westerly direction. Mweelrea, 2688 feet, is the highest summit in the west of Ireland, north of Brandon. Seen at a distance it appears to be continuous with the rest of the mountain land around Doo Lough, and these high table-lands, north of Killary fiord at the south-west corner of Mayo, will be best considered as one mass divided into three distinct portions by low-lying river valleys. These mountains are composed of Silurian slates chiefly with sandstones, schists, and conglomerates, and we no longer meet with the dome-shaped or conical summits usual to the quartzite formation. At Cead-na-binnian there is a considerable exposure of gneiss. Plateaus bounded by long ranges of precipices, ridges, and gullies, ending in ravines with sheer sides and dangerous nooks and corners, promised well for alpine botany. Amongst these I climbed every day for a week in constant expectation, but I met with no such variety as I had hoped: there were, however, some interesting discoveries made.

Taking the southern end of Doo Lough as the centre, the three valleys dividing the mountains radiate at about equal angles from this point. Of these, one, that of Delphi, Fin Lough, and Bundorragha

river, runs a little west of south to Killary fiord; while a second, that of Glenummera river, Tawnyard Lough, and Owenduff river, runs east to the Erriff. Between these two valleys and that of the Erriff on the south, none of which are more than 200 feet above sea level, lies a triangular tract of land rising gradually westwards to table-lands, and ridges about 2300 feet. These have no name on the Ordinance Map, and other sources gave me choice of Ben Cregan, Cead-na-binnian, or Ben Gorm, to stand for the mass. The third valley is that of Doo Lough, Lough Cullin, and Lough Connel, running north-west, and leading us by low levels to the sea. Between it and the Glenummera, or rather to the north of these valleys lies a mountainous tract, reaching a height of over 2400 feet in several points and ridges, and cut into by valleys, of which the chief is that of the Glen Laur river; the highest point lies above Doo Lough, and is called by the natives Delphi mountain, while running east from it is a long elevated spur, called Loughty mountain, ending in the Glen Laur valley. As before, the inch Ordinance Map gives no name for these mountains. To the west of Doo Lough valley, and enclosed by it, Killary fiord and the Atlantic, lies Mweelrea fronting the mouth of the fiord and curving in a grand tabular ridge, 2600 feet high, to the north, above two tarns in a coomb at 1200 feet. This ridge bounds a long valley, that of the Owenaglogh river, with an eastward sweep till it terminates in abrupt declivities above Lough Doo and in the black, barren, sunless precipices and gorges of Ascokeerin, around the head of Glencullin. These latter I climbed from base to summit, full of hope, 2000 feet of cliffs, but they yielded no rarities.

In average weather the scenery here is delightful, and there is much to interest the lover of nature. At the mouth of the Killary I saw a pair of golden eagles upon two occasions, and choughs, ravens, and peregrines, all were met with. The pass of Delphi and Doo Lough, buried in the mountains, are the most imposing scenes of wild grandeur in the west.

I spent a week amongst these mountains, chiefly at higher levels, of which I made a careful examination. One or two of the lakes at low levels, and the Atlantic coast line, I did not explore, these being somewhat outside my subject. I endeavoured here, however, as in Kerry last year, to obtain a knowledge of the lowland flora of the immediate neighbourhood with a view to seeing what species are unable to ascend the slopes; and what mountain plants can, in so tempting a situation, descend to sea level. I will first give an account of the northern section of the Mweelrea mountain group, starting as usual with the highest point. The commoner species are not repeated, but will be enumerated under the highest summit of all, Mweelrea. The alpine species occurring are, *Oxyria reniformis*, *Saxifraga stellaris*, *S. oppositifolia*, *Vaccinium vitis-idæa*, *Lycopodium alpinum*, *Salix herbacea* and *Carex rigida*, the last three and *Saxifraga stellaris* alone being frequent. The other three occur, together with *Cystopteris fragilis*, very sparingly in one place only.

Delphi Mt., near Summit.

2550 feet.

Achillea millefolium.
Plantago maritima (var. alpina).
P. lanceolata.

Down West.

2000 feet.

Equisetum palustre.

Down South-West, above Lough Doo.

1600 feet.

Dabeocia polifolia.

1550 feet.

Rosa pimpinelloides.
Lonicera periclymenum.
Salix aurita.
Juniperus communis.

1500 feet.

Betula alba.

800 feet.

Pteris aquilina.

600 feet.

Ilex aquifolium.

400 feet.

Carex pallescens.

Loughty Mt.

(Ridge above Lough Bawn).

Cliff 2458 feet.

Lycopodium alpinum.

2400 feet.

Geum rivale.
Saxifraga oppositifolia.
Antennaria dioica.
Vaccinium vitis-idæa.
Oxyria reniformis.
Salix herbacea.
Cystopteris fragilis.

LOUGHTY MT.—*continued.*

2350 feet.

Achillea millefolium.	Plantago maritima (var. alpina).
Leontodon autumnalis.	Eriophorum polystachyon.
Armeria maritima.	

DOWN TO GLEN LAUR.

1750 and 1630 feet.

Dabeocia polifolia (appears.)

1050 feet.

Saxifraga stellaris.	Montia fontana.

770 feet.

Erica tetralix (appears.)	Myrica gale (appears.)

630 feet.

Epilobium palustre.	Betula alba.
Pyrus aucuparia.	Salix aurita.

500 feet.

Cratægus oxyacantha.

BY GLEN LAUR RIVER, NEAR SHEFFRY.

250 feet.

Rosa tomentosa.	Habenaria chlorantha.
Stachys palustris.	Ceterach officinarum.

LOWER DOWN, TO ERRIFF MEETING.

Thalictrum minus (var. flexuosum).	Crepis paludosa.
Sarothamnus scoparius.	Plantago maritima (inland locality).
Œnanthe crocata.	Utricularia intermedia.
Viburnum opulus.	Habenaria albida.

LOUGHTY MT., DOWN SOUTH TO GLENUMMERA.

2050 feet.

Empetrum nigrum.	Cerastium triviale.

1250 feet.

Bellis perennis.

Loughty Mt. Down South to Glenummera—*continued.*

500 and 400 feet.

Carex fulva.	C. œderi.

Ridge between Glenummera and Erriff.

1000 feet.

Orchis latifolia.	Carex fulva.

Crossing the Glenummera river we come to Ben Cregan and Ben Gorm.

The alpine species met with are: *Oxyria reniformis, Salix herbacea,* and *Carex rigida.*

Ben Gorm Table-land

(Down north and west towards Delphi).

2200 feet.

Potentilla tormentilla.	Juncus squarrosus.
Saxifraga umbrosa.	Ereophorum vaginatum.
Galium saxatile.	Carex pilulifera.
Jasione montana.	Nardus stricta.
Calluna vulgaris.	Agrostis vulgaris.
Vaccinium myrtillus.	Aira alpina.
Thymus serpyllum.	Festuca ovina.
Luzula campestris.	

2150 feet.

Viola sylvatica.	C. rigida.
Salix herbacea.	Blechnum boreale.
Carex pilulifera.	

2100 feet.

Campanula rotundifolia.	Antennaria dioica.

1940 feet.

Pinguicula vulgaris.	Orchis maculata.

1850 feet.

Oxalis acetosella.	Hymenophyllum unilaterale.
Asplenium dilatatum.	

1550 feet.

Plantago maritima.

BEN GORM TABLE-LAND—*continued.*

1200 feet.

Digitalis purpurea.

750 feet.

Pteris aquilina.

200 feet.

Myrica gale. | Carex fulva.

DOWN SOUTH TO KILLARY.

2050 feet.

Erica cinerea.
Pinguicula vulgaris.
Narthecium ossifragum.
Eriophorum polystachyon.
Carex panicea.
C. flava.
Aira flexuosa.
A. cæspitosa.
Lycopodium selago.

2030 feet.

Viola palustris. | Scirpus cæspitosus.

1900 feet:

Lycopodium clavatum.

1850 feet.

Salix herbacea.

1600 feet.

Luzula campestris.

1350 feet.

Dabeocia polifolia.

1100 feet.

Drosera rotundifolia. | Schœnus nigricans.

800 feet.

Anagallis tenella.

DOWN EAST TO ASHLEACH BRIDGE.

2030 feet.

Armeria maritima.
Oxyria reniformis.
Carex rigida.
Hymenophyllum unilaterale.

DOWN EAST TO ASHLEACH BRIDGE—*continued.*

1880 feet.

Empetrum nigrum. | Salix herbacea.

800 feet.

Erica tetralix.

WET BOG BY EERIFF RIVER.

Carex filiformis.

We will next examine Mweelrea, not only the highest mountain in Connaught, but with much the most considerable extent of elevated ground. The alpine species are: *Saxifraga stellaris, Sedum rhodiola, Hieracium anglicum, H. iricum, Arctostaphylos uva-ursi, Oxyria reniformis, Salix herbacea, Carex rigida, Aira alpina, Lycopodium alpinum, L. selaginoides, Isoetes lacustris.*

MWEELREA SUMMIT.

2680 feet.

Potentilla tormentilla.	C. binervis.
Saxifraga umbrosa.	Scirpus cæspitosus.
Calluna vulgaris.	Luzula sylvatica.
Vaccinium myrtillus.	L. campestris.
Thymus serpyllum.	Juncus squarrosus.
Rumex acetosa.	Nardus stricta.
R. acetosella.	Anthoxanthum odoratum.
Eriophorum vaginatum.	Agrostis vulgaris.
Carex pilulifera.	Aira cæspitosa.

Festuca ovina.

2640 feet.

Armeria maritima.

2600 feet.

Campanula rotundifolia.	Plantago maritima.
Solidago virgaurea.	Salix herbacea.
Melampyrum pratense.	Carex rigida.

Aira flexuosa.

EAST AND SOUTH-EAST TO BUNDORRAGHA.

2590 feet.

Hymenophyllum unilaterale.

2440 feet.

Salix herbacea.

EAST AND SOUTH-EAST TO BUNDORRAGHA—*continued.*

2380 feet.

Lastræa filix-mas. | L. dilatata.
Polypodium vulgare.

2250 feet.

Blechnum boreale.

2000 feet.

Hypericum pulchrum. | Pedicularis sylvatica.

1900 feet.

Ranunculus ficaria. | Digitalis purpurea.
Stellaria uliginosa. | Primula vulgaris.
Poa annua.

1850 feet.

Vicia sepium. | Epilobium palustre.
Lysimachia nemorum.

1600 feet.

Asplenium trichomanes.

1520 feet.

Thalictrum minus. | Hieracium anglicum.
Lathyrus macrorrhizus. | Plantago lanceolata.

1500 feet.

Stellaria uliginosa. | Epilobium montanum.
Plantago lanceolata.

1430 feet.

Trifolium repens. | Sedum rhodiola.

1370 feet.

Thalictrum minus. | Carduus palustris.
Salix aurita.

1330 feet.

Veronica chamædrys.

1260 feet.

Antennaria dioica.

LEVEL OF LUGALOUGHAUN.

1205 feet.

Ranunculus repens.	Myriophyllum alterniflorum.
R. acris.	Callitriche hamulata.
R. flammula.	Senecio aquatica.
Subularia aquatica.	Lobelia dortmanna.
Alchemilla vulgaris (var. montana).	Littorella lacustris.
	Potamogeton natans.
Galium palustre.	Sparganium minimum.

Eleocharis palustris.

DOWN OUTER RIDGE, SOUTHWARDS.

1100 feet.

Spirea ulmaria.	Hedera helix.
Lathyrus macrorrhizus.	Dabeocia polifolia.
Lonicera periclymenum.	Erica tetralix.

Schœnus nigricans.

1050 feet.

Carex glauca.

1020 feet.

Callitriche platycarpa.	Prunella vulgaris.

Carex vulgaris.

1010 feet.

Salix phylicifolia (upper limit).

1000 feet.

Juniperus nana.	Salix repens.

980 feet.

Potamogeton polygonifolius.	C. stellulata.
Carex ampullacea.	Lastrœa œmula.

900 feet.

Osmunda regalis.

750 feet.

Drosera anglica.	D. intermedia.

650 feet.

Pinguicula lusitanica.

DOWN OUTER RIDGE, SOUTHWARDS—*continued.*

550 feet.

Salix phylicifolia (lower limit).	Myrica gale.

300 feet.

Lycopodium selaginella.

DOWN CENTRAL (OWENAGLOCH VALLEY).

480 feet.

Cynosurus cristatus.	Equisetum sylvaticum.
Poa fluitans.	E. limosum.
Lastrœa oreopteris.	Pteris aquilina.

450 feet.

Pyrus aucuparia.	Fraxinus excelsior.
Ilex aquifolium.	Arundo phragmites.

DOWN CLIFFS S. E. TO LUGALOUGHAUN LAKE.

2240 feet.

Saxifraga stellaris.	Oxyria reniformis.

2100 feet.

Ranunculus acris.	Taraxacum dens-leonis.
Cardamine hirsuta.	Euphrasia officinalis.
Cerastium triviale.	Jasione montana.
Angelica sylvestris.	Aira alpina.
Chrysosplenium oppositifolium.	Lycopodium selaginoides.

1960 feet.

Valeriana officinalis (and at lake).

1650 feet.

Saxifraga stellaris.
Oxyria reniformis. } (lower limit).

1400 feet.

Erica cinerea (upper limit).

DOWN SOUTH TO BUNNAGLASS.

2500 feet.

Leontodon autumnale.

2400 feet.

Viola palustris. | Orchis maculata.

2000 feet.

Hypericum pulchrum.

1800 feet.

Thalictrum minus. | Carex rigida.

1600 feet.

Carex vulgaris.

1500 feet.

Erica cinerea. | Dabeocia polifolia.

1140 feet.

Salix repens.

1000 feet.

Carduus pratensis.

800 feet.

Erica tetralix. | Carex fulva.
Myrica gale. | Pteris aquilina.

700 feet.

Arctostaphylos uva-ursi (to sea). | Quercus robur.

500 feet.

Rosa pimpinellifolia. | Sedum anglicum.

130 feet.

Rubia peregrina.

100 feet.

Erica mediterranea.

ROUND RIDGE ABOVE L. BELLAWAUM TO LOUGH DOO, EASTWARDS.

2450 feet.

Cerastium triviale. | Carex pilulifera.

2000 feet.

Carex pulicaris.

1600 feet.

Hieracium anglicum. | Molinia cœrulea.

1450 feet.

Carduus pratensis.

1400 feet.

Pyrus aucuparia.

940 feet.

Pteris aquilina.

550 feet.

Carex pallescens.

ASCOKEERIN CLIFFS, EASTWARDS TO GLENCULLEN.

2660 feet.

Sedum rhodiola. | Carex rigida.

1640 feet.

Carex rigida.

1450 feet.

Thalictrum minus, to 400 feet. | Chrysosplenium oppositifolium.

Primula vulgaris.

400 feet.

Sanicula europœa. | Ilex aquifolium.

Betula vulgaris.

EAST OF L. BELLAWAUM TO TAWNYORNAN, SOUTHWARDS.

2500 feet.

Thymus serpyllum. | Aira alpina.

Lycopodium alpinum.

East of L. Bellawaum to Tawnyornan, Southwards—*continued.*

2400 feet.

Carex pilulifera. | C. panicea.

2300 feet.

Orchis maculata.

2100 feet.

Salix herbacea.

2000 feet.

Carduus pratensis.

1900 feet.

Angelica sylvestris. | Carex flava.

1650 feet.

Salix aurita.

1350 feet.

Digitalis purpurea. | Salix caprea.

1150 feet.

Carduus palustris.

1100 feet.

Juniperus nana. | Equisetum sylvaticum.

750 feet.

Rubus fruticosus. | Betula alba.
Quercus robur. | Eleocharis multicaulis.

To Doo Lough, North-eastwards.

2450 feet.

Salix herbacea.

2300 feet.

Saxifraga stellaris. | Solidago virgaurea.

2200 feet.

Asplenium dilatatum.

To Doo Lough. North-eastwards—*continued.*

2100 feet.

Saxifraga stellaris.	Aira alpina.
Carex rigida.	Lycopodium selaginella.

2050 feet.

Galium saxatile.	Pedicularis sylvatica.
Sedum rhodiola.	Lycopodium selago.

1900 feet.

Carex rigida.

1480 feet.

Menyanthes trifoliata.	Lycopodium selago.

850 feet.

Hypericum androsœmum.	Veronica officinalis.

V. chamædrys.

670 feet.

Asplenium adiantum-nigrum.

650 feet.

Thalictrum minus.	Hieracium anglicum.
Bunium flexuosum.	H. iricum.

550 feet.

Sedum rhodiola.	Campanula rotundifolia.

Nardus stricta.

450 feet.

Asplenium trichomanes.

380 feet.

Rubus saxatilis.	Carex pallescens.

C. pilulifera.

350 feet.

Thalictrum minus.	Hieracium anglicum.

320 feet.

Jasione montana.	Carex pallescens.

250 feet.

Hypochæris radicata.	Corylus avellana.
Antennaria dioica.	Lastrœa œmula.

In addition to the alpine species already mentioned amongst the Mweelrea mountains, other local plants were noticed in new localities, and may be separately mentioned. There are *Rubia peregrina, Scrophularia aquatica, Carex pallescens, C. filiformis, Lotus major, Eriocaulon septangulare, Thalictrum minus, Utricularia intermedia, Habenaria albida, Sparganium minimum, Lycopodium clavatum, Œnanthe lachenalii, Œ. crocata,* and *Rubus saxatilis.*

On the south side of the valley of the Erriff, at the head of Killary fiord, and north of Joyce's river, a range of mountain forms the boundary between the counties Mayo and Galway. From Letterbrickaun, a village and hill about half a-mile east of Leenane, this high land extends, in a north-eastern direction, in a series of extensive and remarkably level table-lands, with numerous small and barren ponds and lakes, at an elevation of about 2000 feet for about six miles, when it gradually subsides. These mountains are variously called—Maumtrasna, Partry, and Letterbrickaun mountains, and the table-land is, I believe, Formnamore table-land. They are chiefly composed of sandstone and sandstone conglomerate, of carboniferous age, with considerable areas of granite and gneiss. The table-land is a waste of disintegrated conglomerate, and the whole chain is unusually barren. As on Croaghpatrick, *Carex rigida* is replaced by *Carex flava*. I have also noticed this on the Galtee mountains in Tipperary. The only alpine species observed were *Salix herbacea, Juniperus nana,* and the sub-alpine *Hieracium anglicum. Aira alpina,* an alpine form of *A. cæspitosa,* is abundant.

The following notes were taken :—

Maumtrasna and Letterbrickaun.

2150 feet.

Hieracium anglicum.

2130 feet.

Eriophorum polystachyon.

2120 feet.

Antennaria dioica.	Vaccinium myrtillus.
Solidago virgaurea.	Juncus squarrosus.
Campanula rotundifolia.	Nardus stricta.
Calluna vulgaris.	Aira alpina (and at 2100).

1850 feet.

Stellaria uliginosa (and at 1750).	Salix herbacea.
	Carex flava.

Lycopodium selago.

MAUMTRASNA AND LETTERBRICKAUN—*continued.*

1800 feet.

Empetrum nigrum.

1750 feet.

Ranunculus ficaria.	Epilobium palustre.
Geum rivale.	Erica cinerea.

LETTERBRICKAUN, DOWN WEST.

2000 to 1950 feet.

Salix herbacea.

1900 feet.

Dabeocia polifolia.	Orchis maculata.

900 feet.

Bellis perennis.	Carex vulgaris.

DEVIL'S MOTHER, N.-WEST SIDE.

1900 feet.

Viola palustris.	Pinguicula vulgaris.

1520 feet.

Sparganium minimum.	Carex ampullacea.
Eriophorum angustifolium.	Juncus uliginosus.

MAUMTRASNA TO GOWLAN BRIDGE, NORTHWARDS.

1800 feet to 1350 feet.

Juniperus nana (upper inland limit).

800 feet.

Erica tetralix.
Pteris aquilina. } Upper limit.

750 feet.

Myrica gale.

The last mountains considered (Maumtrasna) are partly in Mayo, partly in Galway, and they are apparently no great acquisition to either county, viewed botanically or in any other way.

Travelling southwards, we shall now take the Galway mountains in order, and there will be found on the whole a steady increase in the number of alpine plants. West of Leenane, on the Killary, the land rises at once to form another chain of mountains which stretches southwards to Maumturkmore. From this a ridge of dome-shaped quartzite mountains sweep round south-east and east to Maumeen, where there is a deeper valley than elsewhere, and then, bending more and more eastwards, it ends with the isolated lumps Corcogemore and Leckavrea (Shanafolia), above Lough Shindillia, at the Halfway-house from Clifden to Oughterard. The axis of this range would be probably about twenty miles; but after walking the whole length, summit after summit, from the Halfway-house to Leenane hotel, I concluded it to be nearer double that distance on foot. A zig-zag series of beehives best gives an idea of this remarkably bold and conspicuous range; each beehive being connected with its successor and predecessor by ridges, frequently several hundred, or even a thousand feet down, and usually altogether out of the lines of summits, and not even visible from them, so that compass bearings often lead one far astray. Add to this that the footing is mostly a loose detritus of heavy angular blocks of quartzite, bare of all sod or vegetation for miles, and it will readily be conceived that this is anything but a gentle day's stroll. These plateaux and truncated mounds seem more the shattered remnants of a mountain range that nature is endeavouring to efface, rather than soften with any of her charms. Wherever there appeared a chance I made detours and searched for varieties, and at the southern end of the chain, especially about Maumeen, which I examined carefully, I succeeded in finding a few, some of which had previously been observed; but, having passed that oasis, my object became more and more steadfastly fixed to hurry out of these interminable wastes before nightfall, and to visit them no more. The Maumturk range is the tangled cluster of the Twelve Bens, stretched out in a curved line with their tops rubbed off. The heights are about the same, commonly 2000 feet to 2400 feet, and all are chiefly quartzite. The chain has, however, lost most of its peaks, the compact mass of the Bens having been better able to resist the wearing action of the glacial period—during which time the ice-sheet appears to have buried the highest points of these mountains—and the denudation of subsequent times. The alpine species observed were:—*Thalictrum alpinum*, *Saxifraga oppositifolia*, *S. stellaris*, *Sedum rhodiola*, *Hieracium anglicum*, and its variety, *H. iricum*; *Juniperus nana*, *Salix herbacea*, *Isoetes lacustris*, *Lycopodium selaginella*, *L. alpinum*. Some other scarce species were observed, as: *Arabis hirsuta*, *Sagina subulata*, *Crepis paludosa*, *Hieracium vulgatum* (var. *gothicum*), *Listera cordata*, *Cystopteris fragilis*, and *Carex filiformis*; the latter only at the base of Leckavrea. *Saxifraga umbrosa* is, as usual, abundant; *Dabeocia polifolia* is an ornament upon

all these mountains, south of Clew Bay. *Alchemilla subsericea* is a characteristic plant amongst the alpine species at Maumeen.

MAUMEEN, ABOVE LAKE; ROCKS LOOKING EAST AND NORTH.

1930 feet.

Sagina subulata.

1800 feet.

Alchemilla subsericea.

1650 feet.

Lycopodium selaginoides.

1580 feet.

Dabeocia polifolia.

1520 feet.

Thalictrum alpinum.	Sagina subulata.

1200 feet.

Arabis hirsuta.	Salix repens.
Hieracium anglicum.	Lastrœa aculeata, and var. lonchitidioides.
H. vulgatum (var. gothicum?).	

1100 feet.

Linum catharticum.	Hieracium vulgatum (var. gothicum?).
Alchemilla subsericea.	H. iricum.
Saxifraga oppositifolia.	Corylus avellana.
Lathyrus macrorrhizus.	Cystopteris fragilis.
Crepis paludosa.	

910 feet.

Saxifraga oppositifolia (lower limit).	Fragaria vesca.
Alchemilla vulgaris.	Carex pulicaris.
	C. binervis.

Triodia decumbens.

LAKE.

770 feet.

Lobelia dortmanna.	Isoetes lacustris.
Carex stellulata.	Osmunda regalis.

LECKAVREA TO MAUMWEE LOUGH, SOUTH-EASTERLY.

1810 feet.

Dabeocia polifolia.

300 feet.

Carex fulva.

100 feet.

C. filiformis.

DOWN NORTHWARDS.

1600 feet.

Sagina subulata. | Juniperus nana.

CORCOGEMORE.

2000 feet.

Potentilla tormentilla.	Erica cinerea (upper limit).
Galium saxatile.	Vaccinium myrtillus.
Saxifraga umbrosa.	Empetrum nigrum.
Scabiosa succisa.	Juncus squarrosus.
Solidago virgaurea.	Carex vulgaris.
Campanula rotundifolia.	C. pilulifera.
Calluna vulgaris.	Aira flexuosa.

Lycopodium selago.

DOWN SOUTH.

1650 feet.

Listera cordata.

1500 feet.

Saxifraga umbrosa (disappears).

DOWN NORTH-WEST.

1900 to 1600 feet.

Salix herbacea.

SUMMIT, WEST OF CORCOGEMORE.

1900 feet.

Carex glauca.

SUMMIT, WEST OF CORCOGEMORE—*continued.*

1800 feet.

Sedum rhodiola.	Hieracium anglicum.

1700 feet.

Saxifraga stellaris.

RIDGE TO MAUMEEN, FROM EAST.

2000 to 1950 feet.

Antennaria dioica.	Salix herbacea.
Empetrum nigrum.	Lycopodium alpinum.

NORTH END OF RANGE; GLENCROFT ABOVE KILLARY.

300 feet.

Nasturtium officinale.	Carex paniculata.
Lychnis flos-cuculi.	Lastrœa oreopteris.

At the mouth of the Killary, opposite Mweelrea, and a little south of the Little Killary, there stands an isolated mass of gneissose mountains, of which Benchoona, 1975 feet, is the highest point. From it to another summit, about half a mile to the north-west, the surface is only slightly depressed and very rugged. There is a lake near this second summit, at about 1800 feet, in which I gathered *Isoetes lacustris*, with fronds 15 inches long. This detached clump of mountains does not appear to have been previously visited by a botanist. I did them on the afternoon of a morning spent upon Mweelrea; taking a boat across the Killary, and exploring across the hills above Salrock. I was informed that the maiden-hair fern had been gathered in this neighbourhood in quantity by an Englishman. I met with it nowhere in Galway. A few alpine species were noticed: *Thalictrum alpinum*, *Hieracium anglicum* (var. *iricum*), *Salix herbacea*, and *Lycopodium selaginella; Thalictrum minus* and *Sagina subulata* were also gathered. The two Thalictrums are, it will be seen, confined to distinct zones; the latter being chiefly amongst loosely-constructed gneissose cliffs looking north-east. This rock is frequently uncommonly dangerous to climb. About Salrock I gathered *Rubia peregrina*, which I also found opposite on the Mweelrea side. In small lakes east of Lough Fee, *Eriocaulon septangulare* is abundant, along with the two water-lilies, at about 200 feet above sea level. *Eleocharis multicaulis* is now a characteristic plant, and much more abundant than in Mayo. *Utricularia intermedia* was gathered here also, and *Œnanthe crocata*, rare in

the west, was observed at Derry-na-Sliggan, on the shores of Killary Fiord, as was also *Carex flava* (var. *lepidocarpa*). This Œnanthe becomes a sea-coast plant in the west of Ireland from Galway northwards.

BENCHOONA.

1970 feet.

Sagina subulata.

1900 feet.

Empetrum nigrum. | Salix herbacea (to 1680 feet).

1800 feet.

Littorella lacustris. | Isoetes lacustris.

1600 feet.

Thalictrum alpinum (to 1300 feet).

1500 feet.

Lycopodium selaginella.

900 feet.

Thalictrum minus (to 680 feet). | Hieracium anglicum (var. iricum).

700 feet.

Asplenium ruta-muraria.

500 feet.

Alchemilla vulgaris. | Hymenophyllum unilaterale.

Finally, there remains to be considered the mountainous district of Bennabeola—the Twelve Bens of Connemara. There are in reality seventeen more or less detached summits, from about 1500 to 2400 feet in height. These are huddled together in a compact mass, though several valleys cut far into them. They are well known to all lovers of mountain scenery, and their white and fantastic cluster of rugged points and ridges is one of the chief beauties and attractions in the Connemara district. The formation is chiefly quartzite; but, fortunately for botanists, one or two peaks are mainly composed of a more productive and tractable clayey schist. The valleys penetrating farthest to the heart of the mountains are, Glen Inagh from the east, Glencoaghan from the south, and Owenglin from the west. No road leads up any of these valleys for much distance, and a guide would

invariably bring a visitor up some peak, probably Derryclare or Benlettery, to obtain his view of the scenery. In order to understand and properly appreciate these mountains, one should penetrate to the head of these glens and ascend them. Glencoaghan is, perhaps, the finest scenery; while Owenglin will lead the botanist to something worth his trouble.

Well-known mountains like these, within easy access of good roads and first-rate hotels, and famed far and wide for their scenery, would not be expected to yield fresh matter of interest. I found, however, a detached mountain peak here which was quite a treat to study botanically, so well does it illustrate the peculiar tastes of alpine plants, and such an interesting assemblage does it contain. To botanists this mountain has been *terra incognita*, and I appeal to them and others who may in future visit this locality to be chary of gathering specimens. In fact, were it not that my labours are the property of the Academy, and knowing how plants suffer, even to extermination, from the hands of predatory collectors, I would hesitate ere I disclosed my discovery.

Muckanaght, 2155 feet, is about two and a-half miles south of Kylemore: two other Bens, Benbaunbeg [1] and Benfree, intervene directly in this line, which was the route I took the first time I visited the northern side of Bennabeola. The upper half of this conical peak is disconnected; below that it is joined by necks to Benbaun south on the east, and Bencullagh on the west. From the summit it looks into the heart of Bennabeola on the east, opening up ravine, peak, and ridge in a most satisfactory manner, and is altogether the most picturesquely situated of the group, as well as the best for disclosing the "lay of the land." On the north it is connected by a ridge at about 1000 feet with Benfree; on the south it slopes in a series of abrupt declivities to the low valley at the head of Owenglin. The rock dips eastwards, exposing similar ledges on the north and south faces. No mountain could be better adapted for exhibiting the rigorous laws which govern the distribution of alpine plants. On the northern face at least a dozen species occur, several of these profusely. Half an hour's scramble will take us round to the south face, to a similar series of rocky declivities, and with the solitary exception of *Sedum rhodiola*, every alpine plant has disappeared, while lowland species take their place at the same level, several reaching unusually high. The change is remarkably well shown here, since in common with other mountains in the west, the alpine flora of Muckanaght is best developed at a zone of 1300 to 1800 feet, and fails gradually to the summit, so that keeping the same level around the side of the mountain, this gradual disappearance is very striking. *Salix herbacea* and *Carex rigida* are exceptions to the above general remark. These

[1] There are two Benbauns in the Twelve Bens; the northern and smaller one may be called Benbaunbeg.

usually—the former always—reach the summits of whatever mountains they occur upon, but they are quite as rigorously confined to the northern and north-eastern faces, where all faces and sides are exposed. *Carex rigida*, less abundant than *Salix*, does not occur upon Muckanaght. The following alpine plants grow within a few yards of one another upon this mountain :—

Thalictrum alpinum.	Hieracium anglicum. }
Sedum rhodiola.	H. iricum. }
Saxifraga umbrosa.	Oxyria reniformis.
S. oppositifolia.	Salix herbacea.
S. stellaris.	Polystichum lonchitis.
S. cœspitosa.	Asplenium viride.
Saussurea alpina.	Lycopodium selaginella.

In company with these are *Meconopsis cambrica*, *Geum rivale*, *Crepis paludosa*, and *Cystopteris fragilis*. Of these, three, *Saxifraga cœspitosa*, *Saussurea alpina*, and *Polystichum lonchitis*, have not been previously found in the Mayo and Galway mountains, and several of the others in only one or two localities. So great a variety of Saxifrages does not occur on any other Irish mountain. I have included *S. umbrosa* doubtfully with them to show this feature, as though a mountain plant, it cannot be considered alpine in the same sense as the others. Immediately below the holly fern is a closely allied form of *P. aculeatum*. I have noticed these in company before. A similar companionship exists here and elsewhere in Ireland between *Asplenium trichomanes* and *A. viride*, so much so that on meeting either of the lowland forms below, the others might almost be expected above if suitable situations occur. One other observation and I have done. As if to heighten and illustrate the different atmospheric conditions of the two sides, a pair of ravens disputed my intrusion on the northern side in most audacious fashion, while a pair of peregrines have selected the south side for their breeding ground. The raven is at home amongst plants which are abundant in the polar regions, where it also abounds: the peregrine, a more southern bird, is in keeping with its surroundings. It is seldom these two species breed alongside of one another, and where they do they are at constant war. Nature has here allotted to each its own fit and suitable domain.

There is another station for alpine plants amongst the Twelve Bens—Ben Lettery—which has been examined by botanists. This point lies about two and a-half miles south of Muckanaght, across the wide valley at the head of the Owenglin river, and is immediately above Ballynahinch Lake and the public road on the south. Its northern face thus looks out on Muckanaght, and though the southern side and upper parts from the summit to about 1500 feet are barren and composed of quartzite, yet below that level schistose rocks, and with them alpine plants, appear. *Lycopodium alpinum* and *Thalictrum alpinum* have been recorded from here by Wade. The latter species

has been verified by Isaac Carroll, who has also recorded *Saxifraga oppositifolia* and *Asplenium viride*. The rarest species, *Saussurea alpina*, which is plentiful on the same ground, has not been recorded. I could not, however, meet with *Lycopodium alpinum* on Bennabeola; although being a plant fond of siliceous soil, and occurring elsewhere in the neighbourhood, it is likely enough to occur, and may have been passed over. On Ben Lettery, the upper limit of the alpine species is simply determined by the change of rock to quartzite.

BENCORR AND BENBAUN, DOWN NORTH TOWARDS KNOCKPASHEEMORE.

2390 to 2310 feet.

Potentilla tormentilla.	Scirpus cœspitosus.
Galium saxatile.	Carex binervis.
Saxifraga umbrosa.	C. pilulifera.
Euphrasia officinalis.	Anthoxanthum odorantum.
Calluna vulgaris.	Aira flexuosa.
Vaccinium myrtillus.	Agrostis vulgaris.
Empetrum nigrum.	Lastrœa dilatata.
Juncus squarrosus.	Polypodium vulgare.

Lycopodium selago.

2250 feet.

Silene maritima.	Armeria maritima.
Solidago virgaurea.	Aira cœspitosa.

1900 feet.

Dabeocia polifolia.

1850 feet.

Stellaria uliginosa.

1800 feet.

Molinia cærulea.	Erica cinerea.

1200 feet.

Pyrus aucuparia.

800 feet.

Hymenophyllum unilaterale.

BENBAUNBEG, DOWN NORTH TO KYLEMORE.

1570 feet.

Antennaria dioica.	Salix herbacea.

BENBAUNBEG, DOWN NORTH TO KYLEMORE—*continued.*

820 feet.

Carex pallescens.

750 feet.

Alchemilla vulgaris (var. subsericea).

700 feet.

Quercus robur. | Salix repens.

Lastrœa aculeata.

BENBRACK SUMMIT.

1900 feet.

Salix herbacea.

SOUTH SIDE.

1020 feet.

Asplenium trichomanes.

BENGOWER DOWN SOUTH, TO GLENCOAGHAN.

1200 feet.

Lastrœa œmula.

650 feet.

Mentha aquatica.

250 feet.

Eleocharis multicaulis (most abundant).

DERRYCLARE, DOWN SOUTH.

2300 feet.

Pyrus aucuparia.

2060 feet.

Antennaria dioica.

DERRYCLARE, DOWN SOUTH—*continued.*

2000 feet.

Scabiosa succisa. | Orchis maculata.
Molinia coerulea.

1800 feet.

Arctostaphyllos uva-ursi (abundant).

1600 feet.

Dabeocia polifolia.

950 feet.

Erica tetralix.

BEN LETTERY, SOUTH SIDE.

1500 feet.

Saxifraga umbrosa. | Solidago virgaurea.
Carex pilulifera.

1450 feet.

Dabeocia polifolia. | Erica cinerea.
Lastrœa œmula.

1150 feet.

Juniperus nana.

1100 feet.

Lycopodium selago.

950 feet.

Erica tetralix (upper limit).

800 feet.

Schœnus nigricans.

650 feet.

Eleocharis multicaulis (upper limit).

420 feet.

Hypericum androsœmum. | Triodia decumbens.

Ben Lettery, Northern Side.

1520 feet.

Thalictrum alpinum. | Saxifraga oppositifolia.
Asplenium viride.

1420 feet.

Saussurea alpina. | Plantago lanceolata.

1320 feet.

Rubus saxatilis. | Saussurea alpina.
Lycopodium selago.

1310 feet.

Saxifraga oppositifolia (lower limit).

1300 feet.

Thalictrum alpinum (lower limit).

800 feet.

Drosera rotundifolia. | Erica tetralix.
Crepis paludosa. | Pinguicula lusitanica.

600 feet.

Carex fulva.

Muckanaght, down South Side.

2150 feet.

Calluna vulgaris. | Eriophorum vaginatum.
Thymus serpyllum. | Luzula sylvatica.

And most of the commoner summit species on Ben Corr, and elsewhere.

2000 feet.

Blechnum boreale.

1400 feet.

Hieracium vulgatum (var. gothicum). | Carduus pratensis.
Pinguicula vulgaris.
Nardus stricta.

MUCKANAGHT, SOUTH SIDE—*continued.*

1350 feet.

Lathyrus macrorrhizus.	Prunella vulgaris.
Scabiosa succisa.	Plantago lanceolata.
Antennaria dioica.	Schœnus nigricans.

1250 feet.

Lonicera periclymenum.	Ilex aquifolium.
Hedera helix.	Hieracium vulgatum.

Teucrium scorodonia.

1150 feet.

Lotus corriculatus.	Lastrœa filix mas.
Sedum rhodiola.	L. filix foemina.
Crepis paludosa.	Asplenium adiantum nigrum.
Hieracium vulgatum.	A. ruta-muraria.
Plantago maritima.	A. trichomanes.
Triodia decumbens.	Polypodium vulgare.

MUCKANAGHT, DOWN NORTH SIDE.

2130 feet.

Saxifraga stellaris.	Salix herbacea.

Cystopteris fragilis.

2110 feet.

Thalictrum alpinum.	Carex panicea.
Luzula campestris.	Poa annua.

2050 feet.

Aira cœspitosa.

1900 feet.

Oxyria renifornis.	Oxalis acetosella.

Asplenium viride.

1850 feet.

Ranuculus flammula.

1700 feet.

Thalictrum alpinum (lower limit).	S. oppositifolia.
Geum rivale.	S. stellaris.
Sedum rhodiola.	Saussurea alpina.
	Oxyria uniformis.

MUCKANAGHT, DOWN NORTH SIDE—*continued.*

1700 feet—*continued.*

Plantago maritima. | Carex panicea.
Asplenium viride.

1600 feet.

Cystopteris fragilis (lower limit).

1500 feet.

Meconopsis cambrica.	Saussurea alpina.
Geum rivale.	Polystichum lonchitis.
Saxifraga cœspitosa.	P. lonchitoides.
Hieracium anglicum.	Lycopodium selaginoides.

1470 feet.

Meconopsis cambrica.
Sedum rhodiola.
Saxifraga oppositifolia.
S. stellaris. } Lower limit.
S. cœspitosa.
Oxyria reniformis.
Asplenium viride.

1080 feet.

Asplenium trichomanes. | Hymenophyllum unilaterale.

At the lower levels in this part of Galway the county has been thoroughly well ransacked. I did not feel called upon to make any detailed search, therefore. The following are a few notes taken at the bases of the mountains:—Derryclare Lough, below Derryclare Mt., *Drosera intermedia* very abundant; *Subularia aquatica*, *Utricularia intermedia*, *Carex limosa*, and *Eriocaulon septangulare*, all common. At Kylemore I saw *Hieracium iricum*, and between that and Derry-na-Sliggan, *Helosciadium nodiflorum*, *Veronica scutellata*, and *Carex stricta*. On the north side of Ballinahinch Lake, in bogholes by the roadside, may be seen *Cladium mariscus*, *Carex limosa*, and *C. filiformis*.

I shall now give a general list, including all the mountain species observed, starting at the highest point attained by each, and appending their other more important altitudes throughout the two counties. This list, which is the result of the more local one, has been a tedious compilation, but appeared to me quite necessary. Some slight inaccuracies, arising from confusion of figures, may have crept in; but I have failed to detect any.

GENERAL LIST OF PLANTS

Observed on the Mayo and Galway Mountains, *arranged in descending order.*

Summit of Mweelrea.

2680 feet.

Potentilla tormentilla (Nestl.)—Nephin, 2640; Croaghpatrick, 2510, &c., and downwards. Abundant.

Saxifraga umbrosa (Linn.)—All summits, and downwards to sea-level, near the coast in dry, stony places. Occurs on all aspects, being at home either amongst alpine plants, or where they could not exist. Inland it rarely occurs as a lowland plant, ceasing downwards at 1500 to 1200 feet. No choice of rock.

Calluna vulgaris (Salisb.)—All summits and downwards. Abundant.

Vaccinium myrtillus (Linn.)—Ditto.

Thymus serpyllum (Linn.)—Bengorm, 2200; Croaghpatrick, 1570; Twelve Bens, 2150. Not ascending many mountains, though frequent at considerable heights on the Mweelrea group. Common below. Will not grow on the quartzite.

Rumex acetosa (Linn.)—Summits of all the Mayo mountains, and downwards.

R. acetosella (Linn.)—Croaghpatrick summit. Not universally distributed at upper heights. Re-appearing commonly below.

Juncus squarrosus (Linn.)—Summit of Croaghpatrick; Twelve Bens, 2390.

Luzula sylvatica (Bich.)—Summits of Mayo mountains. Twelve Bens, 2150. Shady cliffs or woods in lowland districts. Rarely on open ground except at mountain summits; usually abundant there.

L. campestris (Willd.)—Bengorm, 2200; Twelve Bens, 2110. Increasing quickly to open moors. Frequent.

Eriophorum vaginatum (Linn.)—Twelve Bens, 2150. Continuous to low levels on moors.

Carex pilulifera (Linn.)—Corslieve, 2025; Twelve Bens, 2390. Frequent to about 1200 feet. Scarce at low levels.

C. binervis (Sm.)—Croaghpatrick, 2350; Twelve Bens, 2390. Very glaucous on Mweelrea. On open moors.

Scirpus cæspitosus (Linn.)—Twelve Bens, 2390.

Anthoxanthum odoratum (Linn.)—Summits of Mayo mountains. Twelve Bens, 2390. Frequent.

Nardus stricta (Linn.)—Maamtrasna, 2120. Soon abundant in dry situation, from 1500 feet downwards, and thrives on the quartzite.

Aira cæspitosa (Linn.)—Twelve Bens, 2250. Common in the Mayo mountains at high levels.

Agrostis vulgaris (With.)—Twelve Bens, 2390.

Festuca ovina (Linn.)—Summits of Nephin and Croaghpatrick. Twelve Bens, 2150.

Summit of Nephin.

2640 feet.

Galium saxatile (Linn.)—Summit of Croaghpatrick. Twelve Bens, 2390; Leckavrea, 2000. Abundant.

Empetrum nigrum (Linn.)—Summit of Croaghpatrick. Corslieve, 2250; Twelve Bens, 2350. Common. Below 300 feet on Achill and Birreencorragh. One of the few species that thrives on quartzite.

Armeria maritima (Willd.)—Mweelrea, 2640. Summit of Croaghpatrick. Twelve Bens, 2250. Ceases as a mountain plant. Croaghpatrick, 1500; Curraun Achill, 1200. Re-appearing abundantly at sea level, and thriving on siliceous rocks.

Aira flexuosa (Linn.)—Mweelrea, 2600. Summit of Croaghpatrick. Twelve Bens, 2390. Common on moorlands.

Lastræa dilatata (Presl.)—Mweelrea, 2380; Twelve Bens, 2390.

Lycopodium selago (Linn.)—Twelve Bens, 2390. Sea level, or near it at Doo Lough. Ceases usually at about 1200 to 1000 feet on the mountains as on Nephin. Seems to prefer siliceous rocks.

Mweelrea.

2600 feet.

Sedum rhodiola (D. C.)—Not seen elsewhere nearly so high. Descends occasionally to sea level; but usually found in alpine situations and with alpine plants. Croaghpatrick, 1740 to 1570; Corslieve, 1600; Achill, 1430 to sea level; Mweelrea, 1430 to 500; Corcogemore, 1800; Twelve Bens, 1700 to 1470, and at 1170.

Solidago virgaurea (Linn.)—Achill, 1730; Twelve Bens, 2250; Maamtrasna, 2120; Leckavrea, 2000.

Campanula rotundifolia (Linn.)—Ben Gorm, 2150; Croaghpatrick, 1900; Corcogemore, 1900; Maamtrasna, 2000. Not unfrequent as a mountain plant, especially in rocky ground of a siliceous nature. Descending to 550 feet on cliffs above Doo Lough; but flowers sparingly.

Melampyrum pratense (Linn.) (var. *montanum.*)—Nephin, 2300; Corslieve, 2250; Croaghpatrick, 1900; Achill, 1730. Rather thinly distributed, and not met with at low levels.

Plantago maritima (Linn.)—Curraun Achill, 1200; Achill, 2200; Twelve Bens, 1700. Rarely occurring inland at low levels. At the base of Nephin in Boughadoon, by the Glenlaur river,

and by Fin Lough. A curiously stunted variety, with broad leaves, and stem an inch and a-half high, occurs at 2400 to 2300 on the Ascokeerin ridge, Mweelrea; and on the summit of Delphi mountain, 2550.

Salix herbacea (Linn.)—Nephin, 2450 to 1880; Corslieve and Nephinbeg, 2320 to 1700; Curraun Achill, 1560; Achill, 2100 to 1900; Croaghpatrick, 1850 to 1750; Mweelrea group, to 1850; Maamtrasna range, 1850; Maamturk range, 2000 to 1600; Benchoona, 1900 to 1680; Twelve Bens, 2130 to 1570. Possibly occurs lower on low summits, since it prefers the tops and ridges of mountains in perfectly exposed situations. This is the commonest alpine plant, and occurs on very nearly all the mountains I visited. More abundant on Mweelrea than elsewhere; on the northern summit it is the chief vegetation straggling amongst moss.

Carex rigida (Good.)—Nephin, 2500; Corslieve and Nephinbeg, 2320 to 1600, and at 860 feet at Scardaun Lake; Achill, 2030 to 1825; Mweelrea group, to 1640. Next to the last, this is the commonest truly alpine species in the west; they are frequently in company on wet ledges, and both thrive on the quartzite.

Mweelrea.

2590 feet.

Hymenophyllum unilaterale (Willd.)—Corslieve, 1750; Achill, 1730; Ben Gorm, 2080. Frequent at low levels in both counties.

Delphi Mt. (Mweelrea Group).

2550 feet.

Achillea millefolium (Linn.)—At 2350 above Lough Brawn on Loughty Mt. Met with nowhere else on the mountains; here it was stunted, consisting of a few rigid radical leaves without stem or flowers. Frequent below.

Plantago lanceolata (Linn.)—A very diminutive form, with slightly succulent, narrow, lanceolate leaves, about an inch in length, and a flowering stem not much higher. Resembles the form of *P. maritima*, mentioned above, in general appearance. Ordinary *P. lanceolata* finds upper limits—on Croaghpatrick, 1630; Mweelrea, 1520.

Summit of Croaghpatrick.

2510 feet.

Poa annua (Linn.)—Ben Gorm and Glenamorig, 2200; Buckoogh and Mweelrea, 1900. Accidentally distributed amongst these heights. Probably the seeds are transported hither by sheep, as this grass only occurred at great heights in the neighbourhood of their runs.

Mweelrea.

2500 feet.

Leontodon autumnalis (Willd.) (var. *taraxaci.*)—Ridge above Lough Brawn, 2350; Mweelrea, 1500 (*L. autumnalis.*) Thence common.

Aira cæspitosa (Linn.) (var. *alpina.*)—To 2100; Ben Gorm, 2200; Maamtrasna, 2120 to 2100. Not met with on the Twelve Bens, or other Galway mountains, and only occurring at great heights. Plentiful in some parts of Mweelrea, and on Maamtrasna (Fornamore) table-land.

Lycopodium alpinum (Linn.)—Ridge above Lough Brawn, 2450; Curraun Achill, 1560; Maamturk range, 2000 to 1950. This, with *Salix herbacea* and *Carex rigida*, are the only truly alpine species which grow on the quartzite mountains. They, especially the present species, appear to prefer a siliceous soil. Plentiful in each locality cited.

Nephin.

2450 feet.

Saxifraga stellaris (Linn.)—To 2400; Nephinbeg and Corslieve, 2000 to 1400; Achill, 2080 to 1825; Mweelrea, 2300 to 1650, and 1050 in Glenlaur; Twelve Bens, 2240 to 1650; Maamturk range, 1700. Rather sparingly distributed.

Mweelrea.

2450 feet.

Cerastium triviale (Link.)—And at 2100; Croaghpatrick, 1370. Abundant below. Scarce at high levels.

Ridge above Lough Brawn, Loughty Mt. (Mweelrea Group).

2400 feet.

Geum rivale (Linn.)—Maamtrasna, 1750; Twelve Bens, 1850 to 1500. A local plant, and not seen elsewhere. Not on the quartzite.

Saxifraga oppositifolia (Linn.)—Maamturk range, 1100 to 910; Twelve Bens; Ben Lettery, 1520 to 1310; Muckanaght, 1700 to 1470. Exceedingly scarce in the only Mayo locality. More plentiful on Muckanaght; but rare in Galway also. Never on quartzite.

Antennaria dioica (Gœrt.)—To low levels at Doo Lough. Occurs on most of the mountains, quartzite or otherwise, from about 2000 to 1000.

Vaccinium vitis-idæa (Linn.)—Very scarce, and unhealthy-looking here. This plant has been recorded from several of the mountains I examined in Mayo and Galway, but I found it only in the present situation. It appeared to me very rare indeed, and I was always on the look out for it.

Oxyria reniformis (Hook.)—Ben Gorm, 2080; Mweelrea, 2240 to 1650; Croaghpatrick, 1740 to 1570; Twelve Bens (Muckanaght), 1900 to 1470. Very scarce. On Croaghpatrick it is plentiful, and very large and luxuriant. In the present locality it is very rare. Never on quartzite.

Cystopteris fragilis (Bernh.)—Very rare in this the only Mayo habitat. Maamturk range (Maumeen), 1100; Twelve Bens (Muckanaght), 2130 to 1600. Very rare in the west, and quite alpine in its mountain localities; does not occur on the quartzite.

Mweelrea.

2400 feet.

Viola palustris (Linn.)—Maamtrasna, 1900; Ben Gorm, 2030.

Orchis maculata (Linn.)—Maamtrasna, 1900; Mweelrea, 2300; Twelve Bens, 2000.

Carex panicea (Linn.)—Ben Gorm (Mweelrea group), 2050; Croaghpatrick, 1650; Twelve Bens (Muckanaght), 2110 feet. Remarkably luxuriant and glaucous, with glumes and fruit concolorous, sooty black, on drooping spikelets in alpine situations on Muckanaght.

Twelve Bens.

2390 feet.

Euphrasia officinalis (Linn.)—Mweelrea, 2100; Croaghpatrick, 1740. Scarce at high levels.

Polypodium vulgare (Linn.)—Mweelrea, 2380. Soon becoming common.

Mweelrea.

2380 feet.

Lastræa filix-mas (Presl.)—Twelve Bens, 1150; var. *abbreviata*, at 1630 on Croaghpatrick. Not plentiful.

Above Lough Brawn.

2350 feet.

Eriophorum polystachyon (Linn.)—Buckoogh, 1920; Ben Gorm, 2050; Maamtrasna, 2130.

Twelve Bens.

2300 feet.

Pyrus aucuparia (Gœrt.)—Corslieve, 1700; Mweelrea, 1400. Seedlings, or dwarfed above 1000. Frequent below, and well grown at the base of Nephin.

Mweelrea.

2250 feet.

Blechnum boreale (Sm.)—Croaghpatrick, 1740; Ben Gorm, 2150; Twelve Bens, 2000. Only locally plentiful, and does not thrive on the quartzite.

Twelve Bens.

2250 feet.

Silene maritima (With.)—Nephin, 1870; Birreencorragh, 2000. A sea-coast plant ascending mountains in the maritime counties, like *Armeria maritima* and *Plantago maritima*, and, like them, fond of siliceous soil, or on the quartzite.

Achill.

2200 feet.

Oxalis acetosella (Linn.)—Corslieve, 2000; Ben Gorm, 1850; Twelve Bens, 1900. Common at lower levels from about 1500 feet downwards.

Jasione montana (Linn.)—Ben Gorm, 2220; Croaghpatrick, 1900; Mweelrea, 2100. Not seen so high in Galway; not unfrequent below 1500 feet, especially on siliceous soil.

Ben Gorm (Mweelrea Group).

2150 feet.

Viola sylvatica (Fries.)—At this height var. *Reichenbachiana*.—Croaghpatrick, 1900. Frequent lower; apparently dislikes quartzite.

Maamtrasna Range.

2150 feet.

Hieracium anglicum (Fries.)—Nephin, 1490; Achill, 1430; Croaghpatrick, 1650; Mweelrea, 1600 and 1520 to 650 and 350, about Doo Lough. Maamturk range, 1800 to 1200; Twelve Bens,

1500. Usually alpine, but occasionally found at low levels in Mayo; it is then sometimes indistinguishable from *H. iricum*, which, I believe, is a luxuriant lowland form. Typical *H. iricum* never occurs higher up, or in alpine situations. It may be seen along the roadside at Kylemore and elsewhere. The two forms graduate into one another about Doo Lough and Maumeen.

TWELVE BENS (MUCKANAGHT).

2110 feet.

Thalictrum alpinum (Linn.)—To 1700, and on Ben Lettery, 1520 to 1300; Maamturk (Maumeen), 1520; Benchoona, 1600 to 1300; Croaghpatrick, 1590 to 1570. Apparently on all rocks except quartzite. Like *Lycopodium alpinum*, it seems especially fond of granite or gneiss.

MWEELREA.

2100 feet.

Ranunculus acris (Linn.)—Not noticed ascending to any considerable height elsewhere. Frequent from about 1200 downwards.

Cardamine hirsuta (Linn.)—Croaghpatrick, 1650. Not common at any considerable height.

Angelica sylvestris (Linn.)—And at 1900; Croaghpatrick, 1590. Not seen elsewhere higher up.

Chrysosplenium oppositifolium (Linn.)—And at 1450. Rare on the mountains.

Taraxacum dens-leonis (Desf.)—Croaghpatrick, 1590.

Lycopodium selaginoides (Linn.)—To 300; Maamturk (Maumeen), 1650; Twelve Bens, 1500 to 1320.

BEN GORM (MWEELREA GROUP).

2050 feet.

Erica cinerea (Linn.)—Nephin, 1750; Birreencorragh, 1500; Nephin-beg, 1425; Croaghpatrick, 1690; Mweelrea, 1500 and 1400; Maamtrasna, 1750; Maamturk range, 2000; Twelve Bens, 1800 and 1450. Stunted and scattered above 1600 feet, and hardly general anywhere above 1500.

Pinguicula vulgaris (Linn.)—And at 1940; Buckoogh, 1920; Achill, 1480; Croaghpatrick, 1590; Maamtrasna, 1900; Twelve Bens, 1450. The lower of these upper limits arises from unsuitability of ground; common below.

Narthecium ossifragum (Huds.)—Glenamorig, 1750; Achill, 1480. Abundant below.

Mweelrea.

2050 feet.

Pedicularis sylvatica (Linn.)—And at 2000. Sparingly distributed at high levels in these mountains.

Ben Gorm (Mweelrea Group).

2050 feet.

Carex flava (Linn.)—Croaghpatrick, 1850; Achill, 1730; Curraun Achill, 1560; Mweelrea, 1900; Maamtrasna, 1850.

Delphin Mt. (Mweelrea Group).

2000 feet.

Equisetum palustre (Linn.)—Very unusually high for this plant.

Mweelrea.

2000 feet.

Hypericum pulchrum (Linn.)—Frequent lower.
Carduus pratensis (Huds.)—Birreencorragh, 1100; Mweelrea, 1450; Twelve Bens, 1450. Rarely extending above 1000 feet.
Carex pulicaris (Linn.)—Not frequent till about 1000 feet, as above Doo Lough and on Muckanaght.

Maamturk Range.

2000 feet.

Scabiosa succisa (Linn.)—Buckoogh, 1880; Croaghpatrick, 1650; Twelve Bens, 2000. Common lower.
Carex vulgaris (Fries.)—Buckoogh, 1180; Mweelrea, 1600. Seldom occurring at any considerable height. Common below.

Twelve Bens.

2000 feet.

Molinia cærulea (Mœnch.)—Mweelrea, 1600. Soon becoming common.

Benchoona.

1970 feet.

Sagina subulata (Wim.)—Maamturk range, 1930 to 1520. In crevices on the barren exposed summits of gneissose or quartzite mountains. Rare, but easily overlooked.

MWEELREA.

1960 feet.

Valeriana officinalis (Linn.)—And at 1200. Not unfrequent at the base of the mountains.

BUCKOOGH.

1920 feet.

Juncus effusus (Linn.)—Achill, 1480. Then common.

MWEELREA.

1900 feet.

Ranunculus ficaria (Linn.)—And at 1205. Maamtrasna, 1750.
Stellaria uliginosa (Murr.)—Croaghpatrick, 1370; Maamtrasna, 1850; Twelve Bens, 1850.
Digitalis purpurea (Linn.)—Croaghpatrick, 1280; Ben Gorm, 1200.
Primula vulgaris (Huds.)—Croaghpatrick, 1650.

} Common below.

MAAMTRASNA RANGE.

1900 feet.

Dabeocia polifolia (Don.)—Croaghpatrick, 1390; Loughty Mt., 1750; Mweelrea, 1500; Maamturk, 1810; Twelve Bens, 1900. Though much less abundant, this plant has about the same vertical range as *Erica cinerea*. The two frequently appear simultaneously.

BEN GORM.

1900 feet.

Lycopodium clavatum (Linn.)—Not met with elsewhere.

MAAMTURK RANGE.

1900 feet.

Carex glauca (Scop.)—Mweelrea, 1050. Frequent lower down.

TWELVE BENS (MUCKANAGHT).

1900 feet.

Asplenium viride (Huds.)—Croaghpatrick, 1800 to 1570; Twelve Bens—Ben Lettery, 1520; Muckanaght, 1900 to 1470.

Mweelrea.

1850 feet.

Vicia sepium (Linn.)—Not seen elsewhere on the mountains at any considerable height.
Epilobium palustre (Linn.)—Maamtrasna, 1750. Frequent in lower bogs.
Lysimachia nemorum (Linn.)—Buckoogh, 1180. A lowland species.

Twelve Bens.

1850 feet.

Ranunculus flemmula (Linn.)—Croaghpatrick, 1370; Mweelrea, 1205; Twelve Bens, 1850. Common from 1000 feet downwards.

Mweelrea.

1800 feet.

Thalictrum minus—1450, and 1370 to 350 at Lough Doo, and lower in Glenlaur; Benchoona, 900 to 680. A characteristic plant of Mweelrea; common in Glencullen.

Maamtrasna Range.

1800 feet.

Juniperus nana (Linn.)—Curraun Achill, 1200; Achill, 1300; Croaghpatrick, 1740; Mweelrea, 1000 and 1100; Maamtrasna, 1800 to 1350 (inland); Maamturk range, 1600; Twelve Bens, 1150, and elsewhere; but not met with at low levels.

Maamturk Range.

1800 feet.

Achemilla vulgaris (Linn.)—(Var. *subsericea*) to 1100; Twelve Bens, 750.

Benchoona.

1800 feet.

Litorella lacustris (Linn.)—Buckoogh (Lake Mambrackeagh), 1180. Common lower down.
Isoetes lacustris (Linn.)—Corslieve (Lake Drumderg), 1330; Buckoogh, 1180; Nephinbeg (Scardaun Lake), 860; Maamturk, 770.

TWELVE BENS.

1800 feet.

Arctostaphylos uva-ursi (Spr.)—Nephin, 1660 to 1240; Nephinbeg, 325; Curraun Achill, 1200; Achill, 1300; Mweelrea, 700 to sea-level; Twelve Bens, 1800. One of the few species that likes quartzite. Abundant on the Twelve Bens.

CROAGHPATRICK.

1740 feet.

Hedera helix (Linn.)—Mweelrea, 1100; Twelve Bens, 1250.

CORSLIEVE.

1700 feet.

Crepis paludosa (Mœnch.)—Croaghpatrick, 1590; Maamturk range, 1100; Twelve Bens, 800.

TWELVE BENS (MUCKANAGHT).

1700 feet.

Saussurea alpina (D. C.)—To 1500, and Ben Lettery, 1420 to 1320; Croaghpatrick, 1590 to 1570. More limited in its vertical range than most alpine species, but forming close and considerable patches where it occurs.

CROAGHPATRICK.

1650 feet.

Sagina procumbens (Linn.)—Frequent from 1000 feet down.
Rubus saxatilis (Linn.)—Twelve Bens, 1320; Mweelrea, 380.

MWEELREA.

1650 feet.

Salix aurita (Linn.)—Buckoogh, 1180; Delphi Mt. (Mweelrea group), 1550. Soon becomes abundant.

MAAMTURK RANGE (CORCOGEMORE).

1650 feet.

Listera cordata (R. Br.)—Not seen elsewhere.

Croaghpatrick.

1630 feet.

Senecio jacobæa (Linn)
Rhinanthus crista-galli (Linn.) } Rarely ascending the mountains.

Mweelrea.

1600 feet.

Asplenium trichomanes (Linn.)—Achill, 1430; Croaghpatrick, 1590; Twelve Bens, 1150.

Croaghpatrick.

1590 feet.

Ranunculus repens (Linn.)—Mweelrea, 1205.
Polygala vulgaris (Linn.)—Not commonly occurring at this height, and not so frequent on the mountains as *P. depressa.*

Delphi Mt. (Mweelrea Group).

1550 feet.

Rosa spinosissima (Linn.)—Mweelrea, 500. Frequent lower down.
Lonicera periclymenum (Linn.)—Mweelrea, 1100. Abundant below.
Juniperus communis (Linn.)—This form is rarely seen high up, where it usually becomes *J. nana.*

Mweelrea.

1520 feet.

Lathyrus macrorrhizus (Winn.)—And at 1100; Maamturk range, 1100; Twelve Bens, 1350.

Maamtrasna.

1520 feet.

Sparganium minimum (Fries.)—Buckoogh (Lake Nambrackheagh), 1180; Mweelrea (L. Lugaloughaun), 1205.
Juncus uliginosus (Sm.)
Carex ampullacea (Good.)—Mweelrea, 980. } Frequent below.

MAAMTURK RANGE.

1520 feet.

Hieracium vulgatum (Fries., Var. *gothicum*)—To 1100 feet; Twelve Bens, 1400. This and *H. vulgatum* graduate into one another on the south side of Muckanaght.

DELPHI MT. (MWEELREA GROUP).

1500 feet.

Betula alba (Linn.)—Delphi Mt., 630; Mweelrea, 750.

MWEELREA.

1500 feet.

Epilobium montanum (Linn.)—Rarely seen at any considerable height.

TWELVE BENS (MUCKANAGHT).

1500 feet.

Meconopsis cambrica (Vig.)—To 1470. This rare species was in full flower when I discovered it here, and was then remarkably showy and handsome. The flowers were fully two inches in diameter.

Saxifraga cæspitosa (Linn.)—To 1480. See introductory remarks.

Polystichum lonchitis (Roth.)—Sparingly distributed, and growing immediately over the following closely resembling form.

P. aculeatum (Roth.) (var. *lonchitidiodes.*)—Maamturk range, 1200. I am inclined to think the holly fern grows in this latter locality also.

P. aculeatum (Roth.)—Maamturk range, 1200; Twelve Bens, 700.

ACHILL.

1480 feet.

Polygala depressa (Wend.)—Soon common.

MWEELREA.

1480 feet.

Menyanthes trifoliata (Linn.)—Not seen again for about 1000 feet; then frequent.

MWEELREA.

1450 feet.

Cardamine pratensis (Linn.)—Croaghpatrick, 1370.

Achill.

1430 feet.

Hymenophyllum tunbridgense (Sm.)—Nephin range, 400.

Mweelrea.

1430 feet.

Trifolium repens (Linn.)—Buckoogh, 1180; Croaghpatrick, 1370.

Croaghpatrick.

1370 feet.

Myosotis repens (Don.)—Apparently scarce.
Callitriche stagnalis (Scop.)—Mweelrea, 1020. Rare on the mountains.

Mweelrea.

1370 feet.

Carduus palustris (Linn.)—And at 1150. A characteristic plant below, and very luxuriant by the Glenlaur river. Plants here had flowers an inch and a-half across, and on two or three occasions the stem was branched, bearing three or four large flowers together.

Mweelrea.

1350 feet.

Salix caprœa (Linn.)—Not common for a few hundred feet.

Twelve Bens.

1350 feet.

Prunella vulgaris (Linn.)—Mweelrea, 1020; Birreencorragh, 1100. Rarely on the mountains.
Schœnus nigricans (Linn.)—And at 850. Ben Gorm, 1100; Mweelrea, 1100. Plentiful in many places from about these heights.

Mweelrea.

1330 feet.

Veronica chamædrys (Linn.)—And at 850. Soon frequent.

NEPHINBEG.

1325 feet.

Holcus lanatus (Linn.)—Birreencorragh, 1100. On upper pastures.

CROAGHPATRICK.

1300 feet.

Pteris aquilina (Linn.)—Birreencorragh, 600; Delphi Mt., 800; Ben Gorm, 750; Mweelrea, 940 and 800; Maamtrasna, 800. Not abundant, and apparently averse to quartzite. I have given all the upper limits I observed, since this and *Erica tetralix* are Watson's test-plants for the upper margin of his "sub-arctic zone."

NEPHIN.

1290 feet.

Erica tetralix (Linn.)—Birreencorragh, 1200; Croaghpatrick, 1170; Loughty Mt. (Glenlaur), 770; Ben Gorm, 800; Mweelrea, 1100 and 800; Maamtrasna, 800; Twelve Bens, 950 and 800. See under *Pteris aquilina*. The mean of these levels places this plant a hundred feet above Pteris, which is nearer the truth than their relative position in this summary.

LOUGHTY MT. (GLENLAUR).

1250 feet.

Bellis perennis (Linn.)—Birreencorragh, 1100; Maamtrasna, 900. Rarely ascending the mountains.

TWELVE BENS.

1250 feet.

Ilex aquifolium (Linn.)—Delphi Mt., 600; Mweelrea, 450. Frequent wherever any natural wood remains, and in rocky slopes lower down.

Teucrium scorodonia (Linn.)—Scarce till the valleys are reached.

MWEELREA (LAKE LUGALOUGHAUN).

1205 feet.

Subularia aquatica (Linn.)—Abundant in Derryclare and Ballinahinch lakes. This lake is erroneously recorded in "Flora Hibernica" at 1500 feet above the sea.

Alchemilla vulgaris (Linn.)—Maamturk range, 910; Benchoona, 500. Frequent along the bases of the mountains, especially in Connemara.

Galium palustre (Linn.)—Abundant at low levels.

Myriophyllum alterniflorum (D. C.)—Abundant in the larger lakes below.

Senecio aquaticus (Huds.)—Not seen elsewhere high up, but occurs continuously along the stream from this lake to the base.

Lobelia dortmanna (Linn.)—Buckoogh, 1180; Nephinbeg (Scardaun Lake), 860.

Callitriche hamulata (Kutz.)—A common lake plant in the west.

Potamogeton natans (Linn.)—Buckoogh, 1180. Rare high up, and seldom flowering. In turfy lakes and bog-holes this plant is most variable. The leaves every shape, from linear to ovate.

Eleocharis palustris (R. Br.)—Rare in elevated stations.

Curraun Achill.

1200 feet.

Lotus corniculatus (Linn.)—Twelve Bens, 1150. Not common till low levels are reached.

Maamturk Range.

1200 feet.

Arabis hirsuta (R. Br.)—Not seen elsewhere.

Twelve Bens.

1200 feet.

Lastræa æmula (Brack.)—Mweelrea, 980, and lower; Croaghpatrick, 630. Not plentiful amongst the mountains.

Maamturk Range.

1200 feet.

Salix repens (Linn.)—Mweelrea, 1000, 1140; Twelve Bens, 700. Then abundant along the maritime mountains.

Twelve Bens.

1150 feet.

Triodia decumbens (Beauv.)—Maamturk range (Maumeen), 910. Soon common.

Lastræa filix-fœmina (Presl.)—Abundant below.

Asplenium adiantum-nigrum (Linn.)—Mweelrea, 670. Frequent.

A. ruta-muraria (Linn.)—Benchoona, 700. Rare on mountain cliffs.

BIRREENCORRAGH.

1100 feet.

Linum catharticum (Linn.)—Abundant when dry pastures are reached.

BEN GORM.

1100 feet.

Drosera rotundifolia (Linn.)—Twelve Bens, 800. Then common.

MWEELREA.

1100 feet.

Spiræa ulmaria (Linn.)—Frequent lower down.
Equisetum sylvaticum (Linn.)—Corslieve, 600; Mweelrea, 480. Not unfrequent lower down.

TWELVE BENS.

1100 feet.

Hieracium vulgatum (Fr.)—On Muckanaght, south side, where it varies into *H. vulgatum*, var. *gothicum*.
Corylus avellana (Linn.)—Mweelrea, 250. Frequent below. Very large hazels grow in Boughadoon at the base of Nephin.

LOUGHTY MT. (MWEELREA GROUP).

1050 feet.

Montia fontana (Linn.)—Glenlaur.

MWEELREA.

1010 feet.

Salix phylicifolia (Linn.)—To 550. Not seen elsewhere.

DELPHI MT. (MWEELREA GROUP).

1000 feet.

Orchis latifolia (Linn.)—Seldom occurs so high up, or even nearly as high.
Carex fulva (Good.)—Mweelrea, 800 and 500; Twelve Bens, 600. Not unfrequent on boggy slopes at the mountain bases.

MWEELREA.

980 feet.

Potamogeton polygonifolius (Pourr.)—Abundant in the lower bogs.
Carex stellulata (Good.)—Maamturk range, 770. Probably occurs higher, but I did not meet with it. Abundant lower.

MAAMTURK RANGE.

910 feet.

Fragaria vesca (Linn.)—Soon frequent.

MWEELREA.

900 feet.

Osmunda regalis (Linn.)—Maamturk range (Maumeen), 770. Frequent in glens, and by streams lower down.

BENCHOONA.

900 feet.

Hieracium anglicum, var. *iricum* (Fries.)—Mweelrea, 650. See under *H. anglicum*, at 2150.

NEPHINBEG RANGE (SCARDAUN LAKE).

860 feet.

Iris pseudacorus (Linn.)—Growing side by side with *Carex rigida*. A startling coincidence. I know of no instance either of *Iris* occurring nearly as high, or *Carex rigida* nearly as low. There would usually be a gap of at least a thousand feet elevation between these two plants.

NEPHINBEG RANGE.

850 feet.

Eleocharis multicaulis (Sm.)—Mweelrea, 750; Birreencorragh, 600; Twelve Bens, 650. Especially abundant in the Connemara district, as in Glencoaghan.

MWEELREA.

850 feet.

Hypericum androsæmum (Linn.)—Twelve Bens, 420. Not unfrequent.
Veronica officinalis (Linn.)—Common lower.

CROAGHPATRICK.

820 feet.

Anagallis tenella (Linn.)—Ben Gorm, 800. Characteristic of the low-lying turf-bogs.

TWELVE BENS.

820 feet.

Carex pallescens (Lam.)—Delphi Mt., 400; Mweelrea, 380 and 550. Very rare in the west.

ACHILL.

800 feet.

Sedum anglicum (Linn.)—Common at lower levels.

MWEELREA.

800 feet.

Myrica gale (Linn.)—Delphi Mt., 770; Birreencorragh, 775; Maamtrasna, 750. Characteristic of the low turf-bogs and very rigorously defined in its ascent.

BIRREENCORRAGH.

775 feet.

Alchemilla arvensis (Scop.)—Not seen elsewhere on the mountains.

MWEELREA.

750 feet.

Drosera anglica (Huds.)—Nephin, 500. Common in all the bogs below.

D. intermedia (Hayes)—Commoner than the other *Droseræ*, especially in the wetter bogs about the margin of the big lakes, as at Derryclare and Inagh.

Rubus fruticosus (Linn.)—Never occurs high up. This was, I believe, the variety *R. leucostachys* (Smith).

Quercus robur (Linn.)—Twelve Bens, 700. Fine old native trees may be seen at the base of Nephin.

NEPHIN.

700 feet.

Chiefly usual lowland stragglers from this level.

Lychnis flos cuculi (Linn.)—White at 250 feet, Corslieve. Frequent.
Comarum palustre (Linn.)—Frequent.

TWELVE BENS.

650 feet.

Mentha aquatica (Linn.)—Not common in the mountain district.

MWEELREA.

650 feet.

Pinguicula lusitanica (Linn.)—Frequent to about this height.
Bunium flexuosum (With.)—Common.

CROAGHPATRICK.

630 feet.

Cotyledon umbilicus (Linn.)—Abundant below.
Scilla nutans (Sm.)—A lowland straggler.

CORSLIEVE.

600 feet.

Epilobium obscurum (Schreb.)—Specimens gathered near Delphi House in ditches by the road appeared to me to belong to typical *E. tetragonum* (Linn.). My plants were unfortunately badly preserved.

NEPHIN.

500 feet.

† *Cratægus oxyacantha* (Linn.)—Perhaps introduced.

DELPHI MT.

500 feet.

Carex flava (Linn.)—Var. *œderi*. Not seen frequently.

MWEELREA.

480 feet.

Cynosurus cristatus (Linn.)—Common.
Poa fluitans (Scop.)—Common.

MWEELREA.

450 feet.

Fraxinus excelsior (Linn.)—Handsome native trees occur in the "forest" at the base of Nephin.
Arundo phragmites (Linn.)—Common.

BIRREENCORRAGH.

380 feet.

Cultivation at about 400 feet, the highest seen on the Mayo or Galway Mountains.

Anthemis nobilis (Linn.)—Not seen elsewhere; but this plant properly belongs to roadsides.
Agrostis vulgaris (Linn.)—Var. *pumila.* Not seen elsewhere.

BIRREENCORRAGH.

350 feet.

Nymphæa alba (Linn.)—Frequent.
Hypericum elodes (Linn.)—Frequent.
Utricularia intermedia (Hayne.)—Plentiful in many places, and occurs throughout the districts visited. Often, as by Glenlaur river and near Delphi House, it is found in the slimiest and filthiest mud-holes, where nothing else appears to thrive. I found it invariably (June and July) attached to its hybernacula. *See* Introduction.
Eriocaulon septangulare (With.)—Corslieve, 250. *See* Introduction.
Scirpus fluitans (Hook.)—Plentiful in many places, as about Doo Lough and Derryclare.
Rhynchospora alba (Vahl.)—Corslieve, 250. Not common; but occurs in the wettest bogs in several places.
Carex filiformis (Linn.) } The distribution of these species is given in
C. limosa (Linn.) } the Introduction.

ACHILL.

350 (?) feet.

Adiantum capillus-veneris (Linn.)—Also, I believe, at Salrock.

Croaghpatrick.

300 feet.

Cultivation at about 250 feet, north side.

†*Ulex europæus* (Linn.)—Rare in the mountain districts, and perhaps not native.

Maamturk Range.

300 feet.

Cultivation at about 280 feet, Glencroft.

Nasturtium officinale (R. Br.)—Confined to the low valleys and ditches.
Carex paniculata (Linn.)—Frequent.
Lastræa oreopteris (Presl.)—Also on Letterbrickaun, near Leenane. Occurs very sparingly.

Nephin.

250 feet.

Cultivation at about 200 feet, Boughadoon.

Sanicula europæa (Linn.)—Frequent.

Delphi Mt.

250 feet.

Cultivation at about 230 feet, Glenlaur.

Rosa tomentosa (Sm.)—Less common than *R. canina.*
Stachys palustris (Linn.)—Common.
Habenaria chlorantha (Bab.)—Not unfrequent. *H. bifolia* occurs at the base of Nephin.
Ceterach officinarum (Willd.)—Frequent.

Mweelrea.

250 feet.

Cultivation at about 200 feet, Delphi.

Hypochæris radicata (Linn.)—Frequent.

CORSLIEVE.

250 feet.

Cultivation at about 200 feet, Deel Bridge.

Utricularia minor (Linn.)—About the Killary in several places, but sparingly and much scarcer in the districts visited than *U. intermedia.*

There is little cultivation at the bases of most of the mountains dealt with, and amongst the different ranges there are many extensive glens and valleys whose botanical conditions are not influenced by the hand of man. Several species are strictly confined to the bases of these valleys, although apparently all the conditions requisite for their growth are fulfilled higher up. Some are, perhaps, denied the power of spreading, while, no doubt, a slightly decreasing mean temperature as we ascend drives many competitors from the struggle, and affords space for the hardier sorts to thrive and monopolize the soil. It is of use to obtain a list of these species, which are thus, though ready for the start, compelled to remain below. Plants of cultivation, or affecting roadsides, broken soil, or habitations, do not enter this list, and those belonging to the immediate margin of the sea are also excluded. All are, in fact, plants of a mountainous country, but confined to the lowest levels.

Caltha palustris, Linn.
Nuphar lutea, Sm.
Hypericum quadrangulum, Linn.
Geranium molle, Linn.
G. robertianum, Linn.
Sarothamnus scoparius, Scop.
Lotus major, Scop.
Prunus communis, Huds.
Geum urbanum, Linn.
Rosa canina, Linn. (*R. canina*, Woods.)
Lythrum salicaria, Linn.
Peplis portula, Linn.
Circæa lutetiana, Linn.
Hydrocotyle vulgaris, Linn.
Helosciadium nodiflorum, Koeh.
Œnanthe crocata, Linn.
Viburnum opulus, Linn.
Tussilago farfara, Linn.
Bidens tripartita, Linn.
B. cernua, Linn.
Achillea ptarmica, Linn.
Gnaphalium uliginosum, Linn.
Centaurea nigra, Linn.
Hieracium pilosella, Linn.
Erica mediterranea, Linn.
Scrophularia nodosa, Linn.
S. aquatica, Linn.
Pedicularis palustris, Linn.
Veronica scutellata, Linn.
V. anagallis, Linn.
V. beccabunga, Linn.
Rumex conglomeratus, Murr
R. obtusifolius, Linn.
R. crispus, Linn.
Alnus glutinosa, Goert.
Habenaria albida, R. Br.
Allium ursinum, Linn.

Juncus lamprocarpus, Ehoh.
J. bufonius, Linn.
Sparganium ramosum, Huds.
S. natans, Linn.
Triglochin palustre, Linn.
Cladium mariscus, R. Br.
Scirpus savii, S. et M.
S. setaceus, Linn.
Carex remota, Linn.
C. ovalis, Good.
C. stricta, Good.
C. sylvatica, Huds.
C. præcox, Jacq.
C. hirta, Linn.
Arrhenatherum avenaceum, Beauv.
Equisetum arvense, Linn.
Scolopendrium vulgare, Sm.

XCII.—On the Cranium of a Native of Lord Howe's Island. By A. Macalister, M. D., F.R.S., Professor of Anatomy, University of Dublin.

[Read, December 11, 1882.]

Through the kindness of Lowry Armstrong, Esq., of H. M. S. "Cormorant," I have obtained the skull of a native of this very-little-known island. There are three islands of the south-east Pacific often confounded with each other, and called by this name: the first of these, and the one to which I at present refer, is one of the Queen Charlotte groups in S. lat., 11° 10′, East long. 165°, and is the next land to Egmont Island.

Another island of the same name, or, according to Captain Cook, a set of islets united by a marginal reef, was described and first visited by Wallis in 1767, in S. lat. 36° 50′, and E. long. 154° 21′, in the region known as the Coral Sea; and yet another Lord Howe's Island lies east of New Ireland, of the Solomon group, in S. lat. 5° 30′, and 159° 31′ E. long.

Less seems to be known of the first than of either of the others, and no other cranium has as yet reached this country from it.

The skull in question is cryptozygous, and, to use the term invented for the crania of the neighbouring race of New Caledonians, hypsistenocephalic.[1] It was that of a young man, known during life to some of the persons who had the opportunity of disinterring it some years after its burial. He was supposed to be about twenty-seven, but, from the patent basi-occipito-sphenoidal suture, can scarcely have been so old; he is described as having been black and woolly-haired, as are the others who inhabit the island. The bones are porous; the frontal suture is open for about a centimetre over the nose, but obliterated above; the coronal suture presents the not uncommon character of being nearly toothless for about 5 cm. on each side of the middle line, then for about 3 cm. it is richly toothed, as far as the temporal crest, while the lower 2½ cm. is again smooth.[2] The sagittal suture is accidentally slightly depressed in one place, and its denticulations, slighter and simpler in front, are rich and complex behind. The lambdoidal, also richly toothed, has one wormian bone on the right side near the top of the suture. There is a wormian bone at the top of the left alisphenoid, directly below the line of the coronal, but not occupying more than one-half of the long spheno-parietal suture, which measures 2 cm. The muscular crests are feebly developed; the inion small and rounded, but the impression for the splenius capitis is unusually distinct and flattened outwards, projecting against the mastoid process. The occipital condyles are unsymmetrical, the right being smaller than the left, and the margin of the foramen magnum is

[1] Barnard Davis, "Natuurk. Verhand. v. d. Hollandsche Maatschappij." Haarlem xxiv. deel.

[2] This character I have often seen; it is well marked in some Kanaka and Fijian skulls in our Museum.

raised into a knob behind the right condyle. The right jugular hole is twice the size of the left; the styloid process is small; the mastoid large and thick, especially the left, as the right is a little flattened behind. The glenoid cavity is very much flattened, with scarcely any transverse ridge in front, and a very faint eminentia articularis. The foramen spinosum on the right is confluent with the spheno-petrosal suture. The pterygoid plate is not toothed, but the outer wall of the scaphoid fossa rises into a spur, and the external pterygoid plate has an upper spur for the upper form of the ligamentum pterygospinosum.[3] There is a strong crista verticalis on the anterior and outer part of the external pterygoid plate, in front of the pterygomaxillary fossa. The processus malaris of the maxilla rises along the front of the spheno-maxillary fissure, and almost excludes the malar from the margin. The malar has a well-marked masseteric crest, and the maxilla has a sutura infraorbitalis transversa, while the infraorbital hole is united to the brim of the orbit by the continuation of the fissure. The prelachrymal suture is nearly complete on the left, cutting off an accessory lachrymal, but is not so well marked on the right. The lachrymals have exceedingly sharp crests and deep grooves, but no hamuli. The nasals are narrow, separate, unsymmetrical, with foramina of Wenzel. The anterior nasal spine is sharp, the canine fossa deep, and the zygomatic ridges well marked. The alveolar arches are very large, the palate rather deep, the posterior nares narrow, oblique, the whole aspect of the pterygoid region being constricted at the basal attachment of the pterygoid processes. There is a supernumerary single-fanged tooth between the first and second premolar on the right side internally.

The measurements are as follows:—Length, 179mm.; greatest breadth, 137; frontal breadth, 104; circumference, 505; intermastoid arc, 400; fronto-occipital arc, 340; height, 149; orbital height, 32; orbital width, 37; nasal height, 49; nasal width, 24; basi-alveolar, line, 108; basi-nasal line, 103; palato alveolar length, 62; palato-alveolar width, at last molar tooth, 66; palatine width, 38; width of both posterior nares, 21; height, 24; width of foramen magnum, 29; length, 33; length of spheno-parietal suture, 21. The lower jaw is large, with very little chin; external width at the angles being 105; at condyles, 115; at coronoid processes, 90. The left condyle is 21 long, the right 20; the sigmoid notch is 33 wide; the vertical height of the coronoid process is 64; the inner length of the intercondyloid intervals is 76; and the height at the chin is 32; while the whole length from angle to angle round the lower margin of the chin is 210. From these it will be seen that the altitudinal index is ·83: the latitudinal, much less, is ·76; the orbital, ·86; the nasal, ·48; the alveolo-nasal, ·104; the capacity measured by Busk's choremometer, 1350.

The cranium thus belongs to the type of hypsi-mesaticephalic leptorhine, mesoseme, prognathous, microcephalic skulls, and thus resembles in type the other Melanesians of neighbouring islands.

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[3] See *Proceedings*, Royal Irish Academy, vol. ii. N. S., Science, p. 202.

XCIII.—Further Evidence as to the Existence of Horned Men in Africa. By A. Macalister, M.D., F.R.S., Professor of Anatomy, University of Dublin. (Plate XX.)

[Read, December 11, 1882.]

Some years ago Dr. H. Minchin lent me a photograph, brought home from West Africa by his son, the late Dr. R. Minchin, in which was pourtrayed the head of a West African, with two remarkable exostoses on the maxilla below the orbit. Dr. Minchin, junior, had stated with regard to this man that he had heard of a tribe having this peculiarity, that they were famous as executioners somewhere on the borders of Dahomey.

The peculiarity shown in the photograph (Pl. XX.) consists of two symmetrical, and evidently bony, outgrowths of the infra-orbital edge of the maxilla, in a long-faced and somewhat long-headed negro, with scanty moustache and beard.

I made many inquiries among those acquainted with the west coast of Africa, and though I found several persons who had heard something about the existence of people of the kind, yet I could get no satisfactory account until my friend, Dr. Allan, being appointed Colonial Surgeon at Bathurst, kindly undertook to make inquiries for me. One previous informant told me he had seen a man with spur-like processes on the malar bone, but could give me no definite information of his whereabouts.

Dr. Allan communicated with me that the man in question, whose photograph I had shown him, had come from Akim, in 6° North latitude and 1° East longitude. Dr. Allan obtained also from the late Captain O'Brien a letter, in which that gentleman related that he had made an attempt to get the man to Europe, but that having brought him to the seaport he repented, and could not be induced to go any farther.

By the kindness of Professor O'Reilly I obtained an extract from a letter from his brother, H. F. O'Reilly, Esq., of Cape Coast Castle, in which he says:—"I examined the Kebby man six years ago, and subscribed £5 towards sending him home for examination. The history of that case is this. About six years ago Captain Hay (Houssas) was sent on a mission for the Government to a place called Kebby, I think, in the Diabbee country, north-east of Cape Coast. He there came across this man, and brought him down with him. We all agreed to send him home with Captain Baker, who was then starting for England. Baker took the fellow as far as Akim, where the steamer called; here the man cleared out, and was back in Cape Coast at my place in a few days. He told me that he could get no food on board, and so had run away. There is a bony exostosis on each malar bone over the antrum highmorianum. I was anxious to make a cast of the case at the time, but had no materials. From reasons of my own, and inquiries among well-informed natives, I came to the conclusion that the case was not a congenital malformation, but artificially produced, and that is the

reason I took so little interest in the matter. In fact I was told by some Fantees that it is quite possible to produce this deformity. As to there being a tribe of these men, or even a family similarly affected, that I very much doubt, as I think I must have heard something of it. Mr. Allan had seen this man from Kebby, and I believe he is in Akim country. I have seen plenty of tattooing here on the black skin, and as the pigment does not show well, they cause the granulations from the cut surface to rise from half an inch to an inch above the level of the skin. There would be no difficulty in causing a bony growth to spring from the antrum or from the malar bone by puncturing and applying the stimulants they use in tattooing. I am aware that the Akim country is thoroughly well known to a number of colonial officials, and they have not come across the horned men."

In the Verhandlungen of the Berlin Society for Anthropology, Ethnology, and Primitive History for 1877, an account of this man was noticed; but, from the remarks made by Professor Virchow, the outgrowth seems to have been confounded with one of the commoner pathological conditions of epidermal horn.

In the course of the last week I received from my friend, Dr. Allan, a second letter, dated from Gambia, November 17, 1882, in which he says:—"I enclose you a letter written to me by P. Hughes, Esq., Assistant Colonial Secretary at Sierra Leone. You will see from it that he confirms the certificate given to me by the late Captain O'Brien, and read by you to the Royal Irish Academy.

"Mr. Hughes further informed me, that while in Eastern Akim he saw two men with the horns, and the man described by Captain O'Brien. I think the existence of this peculiar family cannot be longer doubted. The horn is, I believe, an anatomical one, and not due to disease. The task of securing one of these skulls is, I am afraid, a hopeless one."

The letter referred to by Dr. Allan is as follows:—

"Sierra Leone,
"*November 13th*, 1882.

"Dear Sir,—In answer to your letter upon the subject of the horned man, described by Captain O'Brien, I beg to inform you that I have seen the man in question, and that Captain O'Brien's description of him is correct. This person was seen by Captain Hay in Akim in 1875 or 1876, and that officer made arrangements for sending him to England. I believe that he went on board the mail steamer, and then declined to proceed, and was, of course, allowed to return on shore. He was photographed, and copies can be obtained at Elmina, Gold Coast.

"When visiting Akim, in 1877, I observed two other men possessing, although in a much less degree, the peculiarities described in the certificate furnished to you by Captain O'Brien.

"I remain yours very truly,

"Percival Hughes,
"*Assistant Colonial Secretary.*"

The information thus gathered by the indefatigable researches of Dr. Allan is of very great interest. Exostoses, we know, are not at all uncommon in the vicinity of the antrum, and the one figured by Mr. Hilton (*Guy's Hosp. Reports*, vol. i.) is not unlike one of those shown in the photograph. A similar exostosis is described by Samuel Cooper in the *London Medical Gazette*, vol. iv., p. 369.

That outgrowths here may be really race characters is not to be entirely ridiculed, for the neighbouring malar bone, which here, according to Dr. O'Reilly's description, participates in the swelling, certainly shows certain race peculiarities, such as the bigger *Tuberositas malaris* of the Mongolians, and the *Processus marginalis*, whose race peculiarities have been pointed out by Werfer (*Das Wangenbein des Menschen*, Tübingen, 1869); while Hilgendorf describes a separation of the malar into two parts as common among the Japanese (*Mittheilung. der deutschen Gesellschaft für Natur-und-Völkerkunde, Ostasiens*, 1873, p. 1). The examination of this region in the fifty African crania of our University Museum shows that while in one Congo negro there is a little fulness in this region, there is no trace of any enlargement in any of the others.

The Akim negroes speak a negro dialect of the Egwee class, and are of the same race as the Fantees and Ashantis, of which race I have several crania, notices of which I hope to be able to lay before the Academy on a future occasion.

The letter formerly received from Dr. Allan is as follows:—

"MADEIRA,
"*February 26th*, 1881.

"DEAR DR. MACALISTER,—I send you a few lines relative to our conversation of 16th inst. I have learned a few authentic facts *en voyage* about the 'horned men' from Captain O'Brien of the Houssa Force, West Africa. The statement made here is certified below by him. A Captain Hay (now in Tobago, W. I.) had stated that he had seen these men at Akim. We had one of the men *en route* for England, but he refused to proceed eventually. Captain O'Brien saw this man at Elmina, and describes him as follows:—'He was, as regards colour, hair, &c., similar to an ordinary native. The horns occupied the malar region, were about two inches in length, their direction being, I believe, from his description, upwards, outwards and forwards, non-movable, and covered with skin.'"

The certificate of Captain O'Brien was as follows:—

"I certify I have seen a man answering to the above description exactly, and said to be the same person Captain L. Hay alluded to.

"PAUL D. O'BRIEN."

XCIV.—On the Crania of Natives of the Solomon Islands. By Alexander Macalister, M.D., F.R.S., Professor of Anatomy, University of Dublin.

[Read, January 22, 1883.]

The Solomon or Salamon Islands form a large Archipelago, about 700 miles long, made up of two lines of islands, whereof seven are of large size, and about thirty are smaller, and they form the easternmost portion of the Papuan Zoological Province. These islands are chiefly volcanic, margined with coral, well wooded, with a flora rich even for a western Pacific land; but they have from early times acquired for themselves an evil reputation, both in point of unhealthiness and inhospitality on the part of their inhabitants, and hence our knowledge of their ethnology is scanty and fragmentary.

They were discovered in 1668 by Meñdana, and since his time have been visited by Dumont D'Urville (*Voyage pittoresque autour du Monde*, 1835, vol. ii. p. 150); by Brenchley (*Jottings during the Cruise of H. M. S. Curacoa in* 1865: 1873, p. 248); by Redlich, master of the schooner "Franz" (*Journal Geographical Society*, 1874, p. 30); by Erskine in 1853; by Scherzer of the Austrian Expedition (*Novara-reise*, 1861. ii. 429); by Webster (*Last Cruise of the Wanderer:* Sydney, 1863). Inhabitants of these islands have been figured and described by Dumortier (*Atlas Du Voyage au Pole Sud.*), and by Virchow (*Verhand. der Berliner Gesellsch. f. Anthropologie, Ethnologie*, &c., 1877, p. 241). They have been also visited by my former pupils, Dr. Goode and Dr. Forbes, and two years since by H. M. S. "Cormorant," on the occasion of which visit these skulls were obtained by Lowry Armstrong, Esq., R.N., by whom they were presented to me.

There was (1873) but one European resident in the Archipelago, Mr. Perry, at Makira, San Christoval; but no mission station has hitherto taken root. Some years ago a Roman Catholic bishop and fifteen priests chartered a schooner and landed on Ysabel, but ere the prelate had been a few hours on shore he was murdered, and his companions compelled to re-embark (Erskine, *West Pacific Islands*, p. 335). My former pupil, Dr. Litton Forbes, who is well acquainted with the inhabitants of many of the Western Pacific Islands, thus characterizes the Solomon islanders:—"So innately ferocious and bloodthirsty are the natives, that any white man that would live among them must go armed, unless, indeed, his object be martyrdom; otherwise, before he could possibly learn the languages and dialects of his congregation, he would, in mere self-defence, have to send so many souls to Hades,

that the subsequent success of years might not suffice to compensate the loss." Even when brought as labourers to Fiji, Dr. Forbes describes their condition as not much improved. In the work from which I have just quoted (*Two Years in Fiji*, p. 64.) he says, "All, however" (of the Polynesian labourers), "of whatever nationality, seem to regard the Solomon islanders with especial aversion, and even fear." From Dr. Forbes' experience of this transport Polynesian labour, he does not seem to regard it as such a potent civilizing influence for the island native as the late Anthony Trollope represents it to be in his work on *Australia and New Zealand* (vol. i. p. 133). These Solomon islanders, however, in Fiji, even after a short period of residence among others, have been known to steal, kill, cook, and eat any unfortunate people they might find straying near their huts. This cannibalism is habitual. Captain Redlich, of the schooner "Franz," saw a number of men who had cooked a captive whole, and then sold the body in parts, and on expressing his disgust to Mr. Perry, was informed by that gentleman that he had seen as many as twenty bodies cooked at one time for a single feast. Captain Redlich, however, says they seemed to him inoffensive when not excited. They keep the skulls of those whom they have eaten suspended in their canoe houses, along with other ornaments, such as the bones of fishes and curious wood carvings. Mr. Brenchley saw twenty-five such skulls in one place in San Christoval (at Wanga), all of which showed the effects of clubs or tomahawks. They do not seem, like the people of New Ireland, to hang the heads in their own huts. Mr. Brown (*Journal of the Royal Geographical Society*, vol. xlvii., 1877, p. 142) saw in one house in the latter island thirty-five human jawbones hanging from the rafters blackened with smoke: "a smoke-dried hand was hanging in the same house, and just outside I counted seventy-six notches in a cocoa tree, each notch of which the natives told us represented a human body which had been cooked and eaten there." These heads hung up in the canoe sheds have been for the most part robbed of their teeth, of which they make necklaces, such as the one I exhibit. These necklaces are not easily got. Commodore Sir W. Wiseman offered two guns for one and was refused. The late lamented Bishop Pattison, however, brought home three; and Dr. Goode obtained the specimen which is on the table from the island of Ulakua.

Scherzer says of these islanders that they were the most intractable and savage of all the tribes that he visited in the entire Novara voyage; and Brenchley describes them as being intensely excitable—stirred up to madness in a minute. It was here that Mr. Boyd, the owner of the "Wanderer," perished in 1862.

In appearance there is a great variety among the natives. Those of the inland parts of San Christoval, who live in the forest and on the slopes of the hills (which here rise to a height of 4000 feet), are called by the coast-dwelling natives Bushmen, and with these the fishermen, as they name the littoral tribes, are constantly at war.

The heads, consequently, which are found in the canoe houses are generally those of the Bushmen.

The people of San Christoval are said by Brenchley to be wretched, poor emaciated creatures, many of them covered with scaly eruptions, as though their skin was peeling off. This pityriasis is not rare among the Melanesians. Those of the inland districts are puny, but healthier looking. One native of Morrissi, examined by Virchow (*loc. cit.*), was a healthy, well-grown male of twenty; in height 5 ft. 2 in.; hypsi-brachycephalic, with a flat nose; strong, but not very prognathous jaws; skin of a dark blackish-brown colour; and beard black, thick, curly, short. Webster (*loc. cit.*) says they are nearly black, with woolly hair, and the countenance characteristic of the Papuan Negro. The males have the western Polynesian habit of stiffening their hair into mops, though not as largely as the Papuans, with yellowish clay and lime, which cosmetic they call *chinam* (cf. Strauch, *Zeitsch. f. Ethnologie*, vol. ix., 1877, p. 241).

The different islands have for the most part different dialects; and in San Christoval that of the fisher tribes (Bauro), which contain many Polynesian words, differs from that of the Bushmen, which is said to be more like the Ulana dialect.

San Christoval is the fifth largest of these islands, and the best known. The inhabitants are usually hung with ornaments, and wear heavy wooden and shell disks in their ears, sometimes lengthening the lobe considerably. This perhaps is correlated with the fact that in the second of our skulls the tympanic bone is much thickened. They almost all have transversely-placed rods or shells in their noses. They sometimes adorn their heads with handsome shell combs; sometimes they cut their hair in terraces from ear to ear. Mr. Brenchley saw some women who had their hair partially shaved off, or cut close, so as to leave a roadway across their heads. Many men are tattooed in patterns, produced by a series of short incisions, made with obsidian knives. Some of them have very flattened noses, but it does not appear that they increase this by art[1]. They chew betel, and are greedy for tobacco. They wear little or no clothing, and are exceedingly ingenious in their carvings and artistic work, illustrations of which are given by Brenchley. In the neighbouring island of Rubiana, near New Georgia, they prepare skulls as ornaments, colouring them with clay, fastening in artificial teeth of shell and wood, and mother-of-pearl eyes. Such crania are not, as far as I know, prepared or kept in the other islands of the group.

The crania available for comparison with my two are—one in the Hunterian Collection from Ysabel, and one from an island undetermined, presented by Sir Erasmus Wilson; as well as two artifically

[1] The new-born children of the island of Jap (Wuap), near the Pelews, have their noses squashed flat after birth by their parents. They call the operation "Andoweck": see Miklucho-Maclay, *Zeitschrift für Ethnologie*, x., p. 105.

prepared skulls from Rubiana, presented by Dr. Bennett; three described in the "Thesaurus Craniorum" from the Davis Collection from Makira, Christoval, brought home by Dr. Mac Gillivray of H. M. S. "Herald." One in the same collection from Guadalcanar; and one from Rubiana; as well as one in the Dublin College of Surgeons' Museum from Guadalcanar, for the measurements of which I am indebted to Mr. Abraham. Of these all but one are males; and the measurements I have given in the Table at the end (p. 780).

Skull No. 1 is that of a fisherman or Bauro, a phænozygous, hypsidolichocephalic cranium, microcephalic, platyrhine, micro-seme, prognathous, with very large everted alveolar arches; pentagonal in norma occipitalis. The sides of the foramen magnum have been broken; its hinder margin is, however, left at one spot; but the right side is cleanly cut away. The squama occipitis is symmetrically compressed immediately above and behind the asterion, and that region is tumid, especially on the left side. The mastoid process itself is small, but the whole mastoid portion of the temporal is dilated, and the paramastoid internal to the digastric groove is as prominent as the mastoid itself. The tympanic is very thick, especially below and behind; the basilar suture is closed; the occipital condyles unsymmetrical; the inion weak, rounded; the spheno-parietal suture is very short—4 mm. on right, 5 mm. on left; it is depressed on both sides, and placed very obliquely, rising forwards: the glenoid cavity is narrow; the outside of the external pterygoid plate on the left is prolonged into a small *processus pterygoideus tertius*, which margins the pterygo-maxillary fossa. The nasal bones are separate, narrow above, widening a little below, perforated by small foramina; the fronto-nasal sutures is above the fronto maxillary; the lachrymal has no hamulus, and there is a post-lachrymal and pre-ethmoidal constriction of the lachrymo-ethmoidal suture. There is a sutura infraorbitalis verticalis on both sides, to which the malar extends on the right side; and a deep canine fossa. There is an infraorbital eminence at the end of the malar on the right side; and the incisive portion of the alveolar arch is nearly horizontal. The greatest breadth of the arch at second molar tooth is 63 mm.; the palatine length is 46 mm.

Skull No. 2 is that of a Bushman, and it contrasts in many respects with the former; it is also a male, but is widely ovate in norma verticalis; nearly quadrilateral in norma occipitalis: it has a spear-wound above the lambda, and is very narrow in the forehead, 88 mm.; it is mesati-tapeino-cephalic, meso-cephalic, and was probably phænozygous, but has lost both zygomatic arches; it is also micro-seme, leptorhine, and prognathous, but without the prominent incisive arches of the former. The basilar suture is open, but the last molar on each side has been cut. The whole skull is flat-topped, with prominent parietal eminences, which are unsymmetrical, the right being very much farther back. The occiput also is more prominent backwards on the right than on the left side; the spheno-parietal

sutures are longer, not depressed—10mm. on left, 12 on right. The tympanic ring is thin: there is a posterior condyloid hole on the left; only a blind pit on the right, and a larger jugular hole on the right than on the left: the right external pterygoid plate is prolonged to the foramen ovale; the nasal bones are small, depressed, not dilating below. This skull, therefore, belonged to a young male, probably about twenty.

Dr. Abraham has kindly given me the following note concerning the skull from Guadalcanar, in the Museum of the College of Surgeons:—

"This specimen was presented to the Museum of the Royal College of Surgeons in Ireland by Staff-Surgeon P. Keelan, R.N. It was probably the cranium of a young male, as evidenced by the comparative thinness of the bones, the slight development of the muscular ridges and fossa, and the non-ankylosis of the sutures, especially in the case of the spheno-occipital. The teeth which remain in this specimen are, moreover, those of a young subject, with perfect crowns, and with the last molar on the left side not yet irrupted. The premolars, the left canine, and the incisors are wanting; the condition of the alveoli indicates that their extraction was *post mortem*. The upper canine of the right side presents a very remarkable abnormality, its growth being vertically upwards instead of downwards. The crown of the tooth is situated below the margin of the orbit, reaching above the level of the inferior orbital foramen. By pressure it has caused the absorption of part of the outer face of the superior maxilla, so that in the dry skull it has its outer enamel surface quite exposed. In the alveolar margin of the jaw there is no corresponding socket; and there is no evidence of a retained milk canine. The four functional teeth, which have been left in the upper jaw, are stained with betel nut. No lower jaw came with the specimen, having been, no doubt, disjointed and utilized as a bracelet. The basi- and ex-occipital portions of the base of the cranium have been knocked out, probably, as Dr. Keelan, in his letter accompanying the specimen, remarks, to get at the brain for cannibal purposes. From the serious wounds which are to be seen on the vault of the skull, and on the left temple, it appears that the individual must have required a great deal of killing. Dr. Keelan thinks it 'a case of death in fight from tomahawk wounds . . . the victim must have been in flight, closely followed. The sliced wound was probably first inflicted; next, the deep one near the vertex; the remainder—apparently down-cuts—when the victim had fallen to the earth on his right side.'

"In general configuration this cranium does not differ much from the long, rather narrow and high Melanesian type; but in certain points there seem to be considerable differences—for instance, in the nasal and orbital indices, as seen below.

"The principal measurements are :—

"Circumference,	500 mm.
Length (ophryon to occipital point),	178 ,,
Breadth[2] (interparietal),	134 ,,

Cephalic Index = 753, and therefore *sub-dolico-cephalic.*

Nasal height,	48 mm.
Nasal width,	22 ,,

Nasal Index = 458, and therefore *leptorhine.*

Orbital width,	37 mm.
Orbital height,	35 ,,

Orbital Index = 946, and therefore *megaseme.*

"In consequence of the absence of the base of the skull, neither the Capacity, the Alveolar Index, nor the Height Index, could be accurately measured. An approximate estimate, however, for the Height Index would give 770 as the number. Although no attempt could be made to determine the Alveolar Index, it is very evident that the face was prognathous."

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[2] The inter-temporal breadth is the same.

TABLE OF MEASUREMENTS OF CRANIA OF SOLOMON ISLANDERS.

	Capacity.	Circumference.	Length.	Breadth.	Height.	Intermastoid Arc.	Fronto-Occipital Arc Frontal.	Parietal.	Occipital.	Orbital Height.	Orbital Width.	Nasal Height.	Nasal Width.	Basi-Alveolar Line.	Basi-Nasal Line.	Breadth Index.	Height Index.	Orbital Index.	Alveolar Index.	Nasal Index.
No. 1, T.C.D., ...	1175	470	168	120	126	342	120	130	84	31	38	42	23	93	89	714	750	795	1045	548
No. 2, T.C.D., ...	1360	494	178	130	130	365	124	126	102	30	40	46	22	99	98	775	730	750	1010	478
Ysabel (Flower), ...	1450	505	180	135	136	—	—	—	—	35	42	53	24	104	100	750	756	833	1040	453
Solomon Islands (Flower),	—	503	182	132	139	—	—	—	—	32	36	50	23	96	101	725	764	889	950	460
Christoval (Davis), . . .	1456*	507	182	122	130	362	120	135	110	—	—	—	—	—	—	670	710	—	—	—
Christoval (Davis), . . .	1325*	490	170	135	135	375	115	117	120	—	—	—	—	—	—	790	770	—	—	—
Christoval (Davis), . . .	1410*	495	178	125	140	350	120	140	107	—	—	—	—	—	—	700	780	—	—	—
Guadalcanar (Davis), . .	1475*	502	180	130	140	355	117	130	—	—	—	—	—	—	—	720	770	—	—	—
Guadalcanar (R.C.S.I.), .	—	500	178	134	—	—	—	—	—	35	37	48	22	—	—	753	—	946	—	—

* Obtained from Dr. Davis's Catalogue by multiplying the ounces of sand (the unit employed by him) by the co-efficient 1·22 to reduce to cubic inches.

XCV.—On the Morphology of Joints. (Part First.) By Alex. Macalister, M.D., F.R.S., Professor of Anatomy, University of Dublin.

[Read, February 26, 1883.]

In most of the systematic treatises on Human Anatomy the descriptions of the articulations are usually defective and unsatisfactory. The importance of these structures from a surgical point of view caused the anatomists of the end of the last and early years of this century to devote much care to their investigation, and subsequent describers have for the most part been content to follow the accounts of Weitbrecht, Bell, the Coopers, Cloquet, and their contemporaries.

As a consequence of this, the morphological relations of the structures entering into the joints have been largely disregarded, and their anatomy is described from the strictly utilitarian, and not from the scientific, point of view.

The method followed in the dissections of the joints hinders our recognition of the real nature of these parts. In general all the collateral parts are cut away before the ligaments are considered, and hence bands are often described as substantive ligaments which are really deeper attachments of superficial parts.

In the course of a careful series of researches, carried on for the purpose of verifying in detail the materials accumulated by me for a systematic treatise on Human Anatomy, I have been much impressed by the unsatisfactoriness of the state of our knowledge of the morphological anatomy of joints, and I shall, therefore, in this communication, and in those that follow it, endeavour to contribute to the clearing of some of this obscurity. Much of what I shall have to describe is, I doubt not, very well known to those engaged in practical anatomical work, but has not hitherto been put on record.

I have endeavoured to determine the history of the individual joints by the twofold method of embryology and ontology, and in this Paper I desire to summarize some of the general results of my studies.

The embryological history of the larger limb-joints in man may be summed up thus:—At first, on the appearance of the limb, the axis or core thereof consists of undifferentiated mesoblastic cells. In this central mesoblast a process of chondrification commences in the areas wherein the several bones are afterwards to be. In this state are the limbs of the smallest embryo examined by me, one of $2\frac{1}{2}$ cm. long. This transformation begins in limited, nearly central spots, and spreads until it results in the formation of a discontinuous chain of cartilages in the axis of the limb, each cartilage corresponding in place to the bone into which it is about to develop. The end of each of these is attached to the contiguous end of its neighbour by a mass of embryonic connective tissue which fills up the interspace, and which is similar in structure to the primitive unchondrified axis, and to the investing layer, which

still remains surrounding the cartilage. This intervening material ties the cartilages together, constituting a series of syndesmoses, or more correctly (for the intervening substance is not ligament), of joints of the type which Professor Hyrtl has called Agonarthrosis.

The ends of the cartilaginous rods swell, and assume somewhat of what is to be their permanent shape, and in doing so they grow towards each other, in which process the disks of connective tissue intervening between the contiguous ends become thinned in the middle, and finally they disappear in the centre, and the cartilages come in contact with each other, the fissure between the two, where the central disk has disappeared, being the primary cavity of the joint. The connective disk still remains peripherally, but in most joints gradually vanishes from the region between the articular ends, remaining as a continuous girdle of connective tissue around the joint in the form of a capsular ligament, This becomes white fibrous tissue, as does the most of the layer on the surface of the shaft of the cartilage with which this is continuous, and which is now perichondrium.

The chronology of these changes is not easily settled. In an embryo of 3·8 centimeters long the central cavity has begun to appear. In one of 5·6 cm. the cavities are formed and the ligaments are embryonic fibrillar tissue; in a fœtus of the thirteenth week many of the permanent conditions are present.

In such joints as are about to develop inter-articular cartilages, the intervening embryonic connective disks, instead of disappearing, solidify, and much later chondrify, and clefts form on both surfaces between these as substantive elements and the ends of the bones. This, we shall see, is the history of the sterno-clavicular joint. In joints which have partial disks like the menisci of the knee, these are derived from the persistence of the later stage of partial absorption.

The hip-joint in man is developed earlier than the knee; the shoulder and knee develop about the same time; the elbow and ankle are usually in the same condition in the same embryo.

In the joints of adults we find that the ligaments are naturally classifiable, according to their origin, into four groups:—

1st. Those derived from the primitive capsule whose origin we have just traced, and which are consequently continuous with the periosteum. These are the true ligaments of all joints.

2ndly. Those derived from the tendons of muscles which surround joints; thus much of the internal lateral ligament of the knee is derived from material continuous with the tendon of the adductor magnus, and much of the posterior ligament from the semi-membranosus.

3rdly. Those derived from fasciæ. In the primitive development of the limb the bundles of muscle are surrounded by embryonic connective tissue, which, as the muscles become specialized, forms a fibrous sheath around each: these combined sheaths uniting, and fastened together by the circular fibres developed in the deep subcutaneous and sub-adipose layers, form the system of limb-fasciæ and intermus-

cular septa. Where these partitions dip in and come in contact with the capsules of joints they adhere thereto, and form a series of accessory ligaments; thus the pubo-femoral accessory ligament of the hip is formed by the pectineal portion of the fascia lata, and the sciatic ligaments are genetically connected with the inferior involution of the glutæal fascia.

4thly. Those derived from degenerated muscles. Of these, in man we have representatives in the intercostal expansion in front of the external intercostal muscle, and in the posterior sacro-coccygeal ligament; but in lower animals, as in the horse's foot, we find a striking example.

The articular cavities are primarily limited to the spaces between the ends of the bones; but, secondarily, from the formation of bursæ, and from the communication of these with the joints, the cavity becomes extended. The shoulder and the subscapular bursa is an opposite illustration.

A special case of such enlargement occurs in the knee-joint, which is peculiar in its development, as I shall have opportunity of showing on a future occasion when describing my sections. The femoral condyles approach the tibia, each independently, and two independent cavities are formed, between which a ridge of the primitive embryonic disk becomes transformed into fibrillar tissue, forming the crucial ligaments; while the margins of the original inter-articular discs persist as the menisci. The capsule originally flows around the joint close to these, and the tendons all lie external thereto. In the quadriceps tendon a sesamoid cartilage develops (the patella), between which and the front of the capsule there forms a large bursal cavity, under which the front wall of the proper capsule becomes deficient, its shreds persisting as the mucous ligament, and the alar ligaments, and the Haversian pellet of fat. In many animals the tendon of the extensor digitorum arising from the femur passes down in front of the joint under the quadriceps. In the frog this is in front of the anterior wall of the capsule; but in lizards the wall is deficient behind it, and so it passes free through the joint, as it does in so many other animals.

In the second part of this Paper I purpose entering into detailed descriptions of the histories of the individual articulations.

XCVI.—Report on the Entomology of certain Districts in Ulster.

By W. F. De V. Kane, M. A.

[Read, February 26, 1883.]

The problems presented by the distribution of the Entomological Fauna of the British Islands are not less interesting than the similar ones which have engaged the attention of scientific botanists; but owing to the neglect of the former study in Ireland, researches that should have proceeded hand in hand, and thrown mutual light on each other, have been almost exclusively carried on by students of the latter branch of Natural History.

It is true that no certain conclusion can be drawn from the occurrence in this country of such insects as are capable of swift or long-sustained flight, as necessarily indicating a former connexion by land with Great Britain or France, such as Geological evidences point to. But among the order of Heterocera (or moths) are numbers whose females could not have flown across the Channel, some of them being apterous, and others of very feeble powers of flight, or with very local or sluggish habits.

The unaccountable ill success, moreover, which has hitherto attended the efforts of many of our best Entomologists to introduce new species perfectly suitable, in every respect, to new habitats where their food-plant naturally abounds, deepens the obscurity of the problem.

Some able Papers comparing the Irish with the Scotch Entomological fauna (striking similarities between some of which were indicated by Mr. Birchall) have been written by Dr. Buchanan White, of Perth; but they deal with Diurnal Lepidoptera exclusively, which, although our prevailing strong winds are from the S. W., may many of them be credited with having crossed the Channel by flight.

Since, therefore, careful and systematic investigations of our really indigenous Lepidoptera may lead to very interesting conclusions, I venture to suggest some directions in which Irish Entomologists might well labour, so that reliable data may be available for scientific inquiry.

In the first place it is, above all, necessary that the Catalogue of Irish Lepidoptera, compiled by the Rev. Joseph Greene, and subsequently largely added to by Mr. Birchall, should be thoroughly revised, so that no name may appear of any species, the capture and locality of which has not been vouched for either by one of these gentlemen, or some other competent and reliable Entomologist.

In the second place, it would be most advisable that fresh ground should be worked, for hitherto collectors have confined their attention almost exclusively to Killarney, the counties of Dublin and Wicklow, and parts of Westmeath, Galway, and Mayo.

Thus the long reaches of sand-hills or rocky shores around our coasts, luxuriant with every sort of maritime plant, and exposed to various aspects and climatic conditions, have for the most part yet to be explored. Our vast bogs, and numerous lake and river margins, though as yet undisturbed by the intrusion, as in the sister island, of populous towns and manufacturing settlements, have, strange to say, contributed a more meagre list of marsh insects than any one of the English fen districts. And although the woodlands of Killarney and Powerscourt have yielded surprising results to Mr. Birchall and others, yet we may reasonably hope for numerous fresh discoveries in like districts elsewhere in Ireland. For although we have no such treasury of Natural History as the New Forest in Hampshire, yet we should not forget that this country was far more recently than England clothed with dense forests and wild scrub-lands, large tracts of which survived as late as the year 1700.

We may, therefore, reasonably expect to find, wherever traces of any such forest lands still exist, the relics of a formerly abundant entomological fauna.

The objection usually urged, that the damp climate of this country is prejudicial to the multiplication of Lepidoptera, is only valid as regards the sun-loving diurnal Rhopalocera, which swarm even in subarctic regions, however cold and long the winter, provided only the summer is brilliant with sunshine. My report deals with the Macro-Lepidoptera observed in two districts where portions of old forest still survive; but as these remnants are yearly disappearing, or being replanted by more profitable species of timber, I propose, if the subject is thought worthy of the attention of the Academy, to indicate in a future Paper some localities of a like nature which still exist in each province of Ireland, and which might, if examined, contribute new botanic and entomological discoveries. I shall now pass on to give an account of the places explored, but cannot help referring to the loss I sustained in being deprived by the hand of death of the assistance of the accomplished young student of Natural History with whom I was to have been associated; namely, the late F. W. Sinclair. I had but just sketched out the plan of our proposed operations when a fatal illness hurried him to the grave, followed by the hearty regrets of all his friends and acquaintances. These furnished an eloquent testimony to his worth and promise. He left but scanty entomological memoranda, so that much of his experience is lost.

It seems regrettable that no Society exists in this University City, as elsewhere, which would gather together lovers of Natural History such as he, record their researches, and through its members diffuse throughout the country an interest in these humanizing studies.

The districts I examined lie in Ulster, which being for the most part devoid of woods, and devoted chiefly to tillage, has hitherto proved the most unfruitful province to the Entomologist. Although my labours were not ill rewarded, as the appended list of 225 species will show, yet it was unfortunate that the past season has been

throughout the United Kingdom the most barren of entomological results that has occurred for many years.

The preceding winter having been exceptionally mild, while the summer of 1880 (which proved exceedingly prolific of Lepidoptera) succeeded an intensely cold winter, furnished a problem for Naturalists which attracted considerable attention. A careful analysis of reports and observations from various parts of Great Britain, coupled with my own experience, has led me to the conclusion that the scarcity has been most marked in such species as have arborivorous larvæ, and (in certain exposed localities) among those whose food-plant, though low-growing, is fragile, and easily destroyed by wind. I, therefore, conclude that the storms of the summer and autumn of 1881 must have shaken many tree-feeding larvæ from their food, and in certain situations destroyed the foliage of many herbaceous plants, especially on the sea-coast. The mild winter, no doubt, was a factor in the problem, for in such weather slugs, woodlice, and beetles, are more active in their ravages upon such pupæ as are not protected by a stout cocoon, or deeply buried beneath the soil; while on the other hand neither ova nor pupæ have their vitality at all affected by intense frost. My researches were commenced in March last at Favour Royal, the seat of the Rev. J. J. Moutray. This demesne, situate on the border of the county Tyrone, was formerly part of a thick covert of oak, birch, ash, alder, and elm, of some four or five miles in length, which is marked as a wood in some maps of the 17th century. Its original extent can be pretty clearly traced in the designations of the townlands about, some thirty of which commence with the prefix of "Derry," or "Killy." Of this stretch of woodland, to which, doubtless, the old Irish air "The green woods of Truagh" refers, portions consisting of about 220 acres are still preserved in the demesne of Favour Royal and the contiguous woods of Gallagh, Creaghan, and Lismore; while the Deer-park encloses about 180 acres of wild land, sparcely timbered with oak, birch, and alder. The oak and ash now standing of these woods are saplings sprung from stools of trees felled a century or more ago, while birch and alder spring up thickly in every clearing; and holly, hazle, and blackthorn furnish a dense undergrowth throughout.

These thickets, invested with the glamour of a hoar antiquity, are supposed still to be the haunt of the "Loghrie-man" or "Leprechaun," whose wizened face peering out from a mossy stump is said sometimes to startle the lonely scollop-cutter as he bends to his task in the gloom of the wood; and also of an unseen sprite, whose attendant foot-fall, stirring the dead leaves in the autumn gloaming, is wont to mock his homeward steps. About a mile and a-half away is a wild glen called Altadiawol, often referred to by Carleton in his *Traits and Stories of the Irish Peasantry*. This glen runs up into the spurs of the Slieve Beagh hills, and is clothed with thick scrub, while birch, oak, ash, and alder, straggle up the slopes, and hang from the precipitous heights on either hand.

To this, though a promising locality, I was unable to devote much time; for, owing to the unsettled state of the country, I found my nocturnal rambles there were generally superintended by two stalwart members of the Royal Irish Constabulary.

Enthusiasm in so peaceful a pursuit as mine is somewhat chilled by such ominous concomitants.

Thrice in the year I spent a week or a fortnight in that neighbourhood, proceeding from thence to Lough Oughter, where, by the kind permission of Lord Farnham, I was lodged in a "cottage ornée" on the promontory of Killykeen (beautiful wood), an appellation it well merits. The shores and islands of this lake are still partly clothed with remnants of the ancient woods which have given them in many cases their names.

The same descriptions of timber are found here as at Favour Royal, while the underwood is a dense thicket of hazle. Not only were the shores of Lough Oughter anciently wooded, but the west bank of the river Erne, down to its junction with the upper lake of that name, is marked in the old maps as having been a forest.

In this district I was fortunate enough to secure a large variety of species in the early season, some in great numbers, and others of much rarity. The later season I devoted to the examination of the neighbouring demesne of Farnham, which, from its extent and the magnificence of its timber, promised remarkable results.

But from the reasons above alluded to, aided by inclement weather, I took very few species of any kind there, even *Scopelosomia satellitia* being conspicuous by its absence, and only a single specimen of *Agriopis aprilina* occurred, in a demesne full of magnificent oak!

From both localities, however, I have hopes of future additional results from my visits, as I have furnished apparatus to very intelligent persons, who are instructed in their use.

The manor of "Farnane," as it is designated in the Down Survey, *i.e.* "the place of alders," was acquired by an ancestor of the present earl some 230 years ago, when the extensive beech woods, now of colossal size, were most likely planted, and are said to have been the first introduced into Ireland. It is probable that some of the great oaks may date beyond that period, and be survivals of ancient woods which formerly clothed part of that country.

These two localities are very similar in their geological and botanical features, but differ somewhat in elevation, the Favour Royal district averaging about 300 ft., while L. Oughter is 160 ft. above the sea level at low-water. The former is situated at the tongue of the Tyrone coal measures, just at the junction of the Carboniferous and Old Sandstone series; while the latter, Farnham, forms part of the central Limestone plain of Ireland. Though separated by about twenty-five miles of country, very bare of trees, the accordance of their entomological fauna is remarkable, as a glance at the list will show, and this would, doubtless, be more evidenced by further careful research, and would seem to indicate a formerly widespread distribution, several

of the species not having been hitherto met with nearer than Killarney or Wicklow.

The following are some of my most interesting captures, many of them having been recorded only once before in Ireland, and the first three are quite new to our list.

(F. R., *Favour Royal*; F., *Farnham*) :—

Hypsipetes ruberata, F. R.
Emmelesia affinitata, F. R. and F.
Acentropus niveus (Pyralidæ), F.
Hypsipetes impluviata, F. R. and F.
Numeria pulveraria, ,, ,,
Lobophora hexapterata, ,, ,,
Lobophora viretata, F.
Lobophora lobulata, F. R.
Ptilodontis palpina, F.
Cymatóphora duplaris, F. R. and F.
Cymatóphora or, F.
Xylophasia hepatica, F.
Taeniocampa gracilis, F. R.
Biston hirtaria, F.
Nola cristulalis, F. R.
Miana arcuosa, F. R. and F., and several others.

The specimens taken quite confirm the observation of Mr. Birchall, that our Irish Heterocera are frequently characterized by more striking pencilling and brighter colouring than those of England. Whether this proceeds from insular variation, or heredity, is a question which the formation of a good Irish collection might cast some light upon. And it appears to me that a comparison of a good series of our insects, which have apterous females, with those of the Continent would afford some approximation to a test of variation; seeing that their introduction hither must, with little doubt, have taken place at an enormously remote period.

Among the sun-loving Rhopalocera, southern latitudes or warm situations produce brighter colouration, and as we approach sub-arctic regions or higher mountain altitudes paler colours and blurred delineation characterize the specimens. With the Heterocera, however, the contrary, to a certain extent, seems to obtain. Some variations of interest occurred at both localities. The variety "combusta" of *Xylophasia rurea* was somewhat abundant; and at Farnham I took two specimens of the ab. Gallicus (Lederer) of *Hepialus velleda*. The type of *Melanippe montanata*, taken in Shetland (var. Hethlandica), seems identical with some taken at Farnham.

A LIST OF LEPIDOPTERA,

Taken during the year 1882, *at Farnham and its neighbourhood, County Cavan; and the District about Favour Royal, County Tyrone.*

ABBREVIATIONS USED :—F., *Farnham;* F. R., *Favour Royal* (where no locality is appended, the insect has been taken at both places) : ab., *abundant;* v. ab., *very abundant.*

DIURNI.

Pieris brassicæ.
P. rapæ.
P. napi.
Anthocaris cardamines, v. ab.
Argynnis paphia, ab.
Vanessa urticæ, ab.
V. atalanta, F. R.
V. cardui, F. R.
Satyrus (*Pyrarga*) *ægeria,* v. ab.
S. (*Pyrarga*) *megæra.*
Epinephile janira.
E. hyperanthus.
Cœnonympha pamphilus.
Lycæna icarus (*alexis*).
L. argiolus, ab., F. R.

SPHINGIDÆ.

Chærocampa elpenor.
Macroglossa stellatarum.
Macroglossa bombyliformis, F. R., locally ab.

NOCTURNI.

Hepialus velleda.
H. velleda, ab., *gallicus* (*Lr.*)
H. humuli.
Procris (*Ino*) *statices,* F. R., locally ab.
Zygæna filipendulæ.
Nola cristulalis, F. R.
Nudaria mundana, F.
Euchelia jacobæ, v. ab.
Chelonia caja, ab.
Arctia lubricipeda,
A. menthrasti.
Demas coryli.
Pœcilocampa populi, F. R.

GEOMETRÆ.

Urapteryx sambucata, F.
Epione apiciaria.
Rumia cratægata, ab.
Metrocampa margaritata.
Selene illunaria, v. ab.
Odontopera bidentata, v. ab.
Crocallis elinguaria, F. R.
Himera pennaria, ab.
Biston hirtaria, F.
Boarmia repandata.
Tephrosia crepuscularia.
T. biundularia.
Pseudoterpna cytisaria.
Geometra papilionaria.
Iodis lactearia, not scarce.
Acidalia scutulata, ab.

A. bisetata, locally ab.
Cabera pusaria, v. ab.
C. exanthemaria, v. ab.
Strenia clathrata, F. R.
Numeria pulvelaria.
Fidonia carbonaria, F. R.
F. atomaria, F. R.
Abraxis grossulariata.
Lomaspilis marginata, F. ab. at F. R.
Hybernia aurantiaria, F. R.
Anisopteryx æscularia, ab.
Chimatobia boreata, ab.
Oporabia dilutata, ab.
Larentia cæsiata, F. R.
Emmelesia affinitata.
Em. albulata, ab.
Eupithecia abbreviata, F. R.
E. satyrata, F. R.
E. subnotata, F. R.
E. vulgata.
E. tenuiata.
E. exiguata, F. R.
Lobophora hexapterata.
L. viretata, F.
L. lobulata.
Thera simulata, F. R.
Hypsipetes ruberata, F. R.
H. elutata, ab.
Melanthia rubiginata, ab.
M. subtristata, ab.
M. montanata, v. ab.
M. galiata.
M. fluctuata.
Anticlea badiata, ab.
A. derivata, F. R.
Coremia propugnata, F. R.
C. ferrugata, ab.
C. unidentaria.
Camptogramma bilineata, ab.
Phibalapteryx lignata.
Cidaria psittacata, not scarce.
C. corylata.
C. russata, ab.
C. immanata, v. ab.
C. suffumata.
C. silaceata, F. R., ab. at F.
C. testata, F.
C. populata, F. R.
Pelurga comitata.
Eubolia mensuraria.
Anaitis plagiata.

Drepanulæ.

Platypteryx lacertula, F. R.
Platypteryx falcula, F. R.

Pseudo Bombyces.

Dicranura bifida, F.
Ptilodontis palpina, F.

Noctuæ.

Thyatira derasa.
T. batis, F. R., v. ab. at F.
Cymatophora duplaris.
Cym. or, F.
Acronyctia psi.
A. rumicis.
Leucania comma.
L. impura, ab.
L. pallens, ab.
Nonagria fulva.
Hydræcia nictitans, ab.
H. micacea, ab.
Xylophasia rurea, v. ab.
Var. *combusta*, not rare at F.
X. lithoxylea.
X. sublustris, F. R.
X. polyodon, ab.
X. hepatica, not rare at F.
Charœas graminis, ab.
Luperina testacea, F.
Mamestra brassicæ.
Apamea basilinea, v. ab.
A. gemina, ab.
A. fibrosa, not scarce.

A. oculea, ab.
Miana strigilis, ab.
M. fasciuncula, F. R.
M. arcuosa, F.
Grammesia trilinea, ab. at F.
Caradrina blanda, F.
C. cubicularis, v. ab.
Agrotis suffusa, F. R.
A. exclamationis, ab.
Triphæna janthina, F.
T. orbona.
T. pronuba, ab.
Noctua augur, F. R.
N. plecta, ab.
N. c-nigrum, F. R.
N. triangulum, F.
N. brunnea, F.
N. festiva, F. R.
N. dahlii, F. R.
N. rubi, ab.
N. baja, F.
N. xanthographa.
Tæniocampa gothica, v. ab.
T. rubricosa, F.
T. instabilis, ab.
T. stabilis, ab.
T. gracilis, F. R.
T. munda, F. R.
Orthosia lota, ab.
O. macilenta, v. ab.
Anchocelis lunosa, ab.
Cerastis vaccinii.
C. spadicea.
Scopelosoma satellitia.
Xanthia silago, F. R.
X. ferruginea, ab.
Dianthæcia cucubali, F. ab.
Polia chi.
Miselia oxyacanthæ, ab.
Agriopis aprilina, F.
Phlogophora meticulosa, ab.
Euplexia lucipara.
Aplecta herbida, not scarce.
A. nebulosa, ,,
Hadena adusta.
H. dentina.
H. oleracea, ab.
H. pisi.
H. thalassina, ab.
Xylocampa lithoriza, F. R.
Calocampa vetusta, F. R.
Xylina rhizolitha F.
X. petrificata, F. R.
Abrostola triplasia F.
Plusia chrysitis.
P. gamma, ab.
Gonoptera libatrix, v. ab.
Amphipyra tragopogonis, F. R.
Euclidia mi, F. R.

DELTOIDS.

Rivula sericealis, F.
Herminia cribralis.

PYRALIDES.

Aglossa pinguinalis.
Pyrausta purpuralis.
P. ostrinalis, F. R.
Herbula cespitalis.
Cataclysta lemnalis, F.
Paraponyx stratiotalis, F.
Hydrocampa nymphealis, F.
Acentropus niveus, F.
Botys fuscalis.
B. terrealis, F. R.
Pionea forficalis, F.
P. stramentalis, F.
Scopula olivalis, F.
S. prunalis, F.
Scoparia ambigualis.

CRAMBITES.

Crambus pratellus, F. R.
C. dumetellus, F. R.
Crambus tristellus, F.
C. hortuellus, F. R.

TORTRICES.

Tortrix ministrana, F. R.
Teras caudana, F. R.
Argyrotoxa conwayana, F. R.
Sericoris urticana.
Orthotænia antiquana, F.
Cnephasia politana, } F. R.
,, *lepidana*, }
C. musculana, F. R.
Ephippiphora, bimaculana, F. R.
E. trigeminana, F. R.
Semasia rufillana. F. R.
Catoptria ulicetana, F .R.
Xanthosetia zoegana, F.R.
Argyrolepia baumanniana, F. R.
Conchylis alternana, F.

PTEROPHORI.

Pterophorus ochrodactylus, F.
Pt. plagiodactylus, F.
Pterophorus monodactylus, F.

XCVII.—Suggestions on the Development of the Cyclic Law of the Chemical Elements. By Thomas Bayley, Assoc. R.C.Sc.I. (Plate XXI.)

[Read, February 26, 1883.]

In a paper published in the *Philosophical Magazine*, Jan., 1882, in discussing the law, originated by Newlands, and called by him the law of octaves, and subsequently developed by Mendelejeff and L. Meyer under the name of the periodic law, the author pointed out that "the increments of atomic weight which, starting from hydrogen, successively give the points where the atomic volume is a minimum are members of the geometric series (see note, p. 795):

$$a,\ a \times b,\ a \times b_2,\ a \times b_3\ \ldots\ a \times b_n,$$

where $a = 10$, and $b = \frac{10}{6}$."

In the same Paper it was shown that the colour properties of the elements when associated as bases with colourless acids are periodic, the metals in the first and second cycles forming no coloured solutions, and in succeeding cycles those metals only forming coloured solutions which occupy the region of low atomic volume. In accordance with this fact, it was argued that uranium, which is a metal having strongly coloured solutions, a high melting point, and great density, must occupy the mediate position in a cycle, and the atomic weight, 180, was suggested as probable because agreeing with these conditions. Since the Paper was written, however, investigation of the density of uranium tetrachloride and tetrabromide by Zimmermann has shown that the atomic weight of uranium cannot be less than 240, and other researches—that of Setterberg on caesium and that of Nilson on thorinum in particular—have afforded material for the further development of the cyclic law.

The successive terms of the geometric series

$$a,\ a \times b,\ a \times b_2,\ a \times b_3\ \ldots\ a \times b_n,$$

where $a = 10$ and $b = \frac{10}{6}$, are

10, 16·6, 27·5, 45·7, 75·9, 126·0,

and the atomic weights are

11, 27·6, 55·1, 100·8, 176·7, 302·7.

It is therefore probable that the sixth cycle attains to its minimum of atomic volume in the neighbourhood of the atomic weight 300. The progression of atomic weight in the first two cycles is 16, and in the second and third approximately three times sixteen, or 46·4 and 47·5

respectively. Assuming that a similar simple ratio holds good in the progressions of atomic weight that constitute the cycles higher than the fourth, the progression from caesium to the element at the head of the sixth cycle is probably six times sixteen, or about 96, which makes the atomic weight of this element about 226. We may, therefore, anticipate the future discovery of an alkali metal having approximately this atomic weight. Such an element would have a density of 2·5 or thereabouts, and a corresponding atomic volume of about 90. Its melting point would be low, and its chemical affinities intense, and, as is the case with caesium, the metal probably would not be reduced by ignition of the carbonate to whiteness with charcoal. Granting the existence of this element and of a halogen analogous to iodine, the fifth cycle is terminated, and thorinum and uranium form part of the sixth. This implies the existence of an alkaline earth metal with atomic weight about 230, and of an earth metal analogous to Sc and Yt to precede thorinum. Thus:

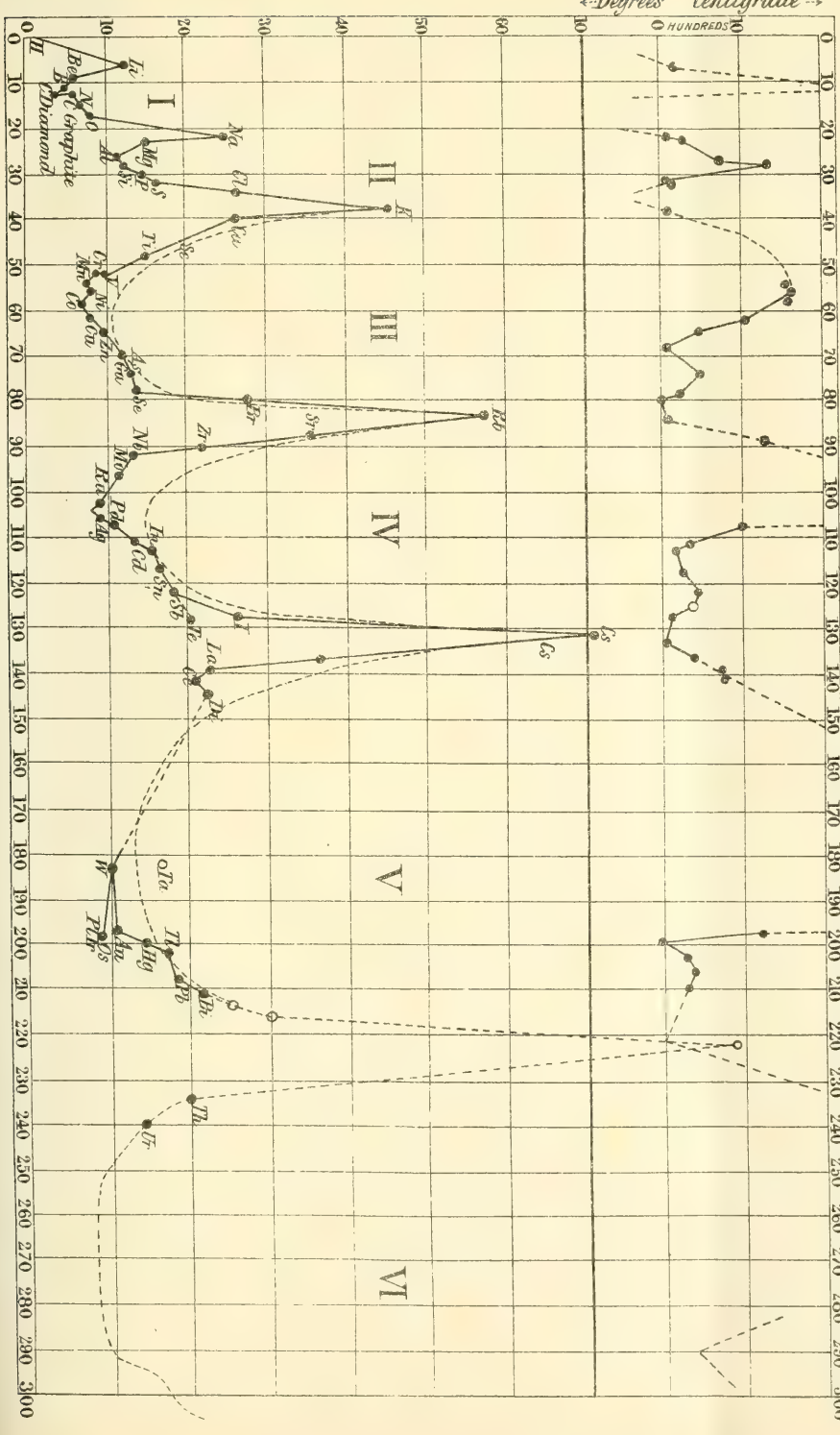
Rb,	Cs,	Alkali metal.
Sr,	Ba,	Alkaline earth metal.
Yt,	—	Earth metal.
Zr,	—	Th.

Thorinum and uranium thus come within the earth region of the sixth cycle, and the coloured solutions of uranium are normal phenomena falling under the law of atomic volume.

The platinoid metals of the sixth cycle probably closely resemble their atom analogues of the fifth, and also have close lateral affinities with each other. Judging by analogy, we may expect to find these higher platinoid metals associated in small quantities with their lower atom analogues, and to experience considerable difficulty in separating them from the latter. Their unsuspected presence in iridium and osmium may possibly account for the upward displacement of these metals in the fifth cycle. In the same way the presence of a higher atom analogue of tellurium (atomic weight about 214) may account for the distortion of the fourth cycle by this element.

Brauner has recently examined the oxides of the metals lanthanum, cerium, and didymium, and has assigned to these elements the positions in the fifth cycle respectively analogous to the elements yttrium, zirconum, and niobium in the fourth. That this is the true sequence and atom analogy of the cerite metals now admits of little doubt, but, at the same time, the progression from yttrium to niobium constitutes a far larger portion of the fourth cycle than the progression from cerium to didymium does of the fifth. The cerite metals all occupy the earth position in the fifth cycle, and in their general properties are elements of the pure earth type, and, as such, strictly analogous to aluminum; and facts thus justify L. Meyer's conception that all three are analogues of the earth elements. They may be said to be cycle analogues of aluminium; and the series analogues of yttrium, zirconium, and

Proc. R.I.A. Plate XXI.



niobium respectively, as shown by Brauner, by the study of their oxides and other compounds and the sequence of their atomic weights.

The space between didymium and the platinum group, occupied with certainty according to our present knowledge only by tantalum and tungsten, is still a *terra incognita* requiring exploration. Erbium may be a member of a second series in the cycle, and tantalum and tungsten higher members of the same period. The determination of the specific heat of erbium and its associates, or, failing this, of the densities of some of their most volatile compounds, would be, at the present time, an important increment of chemical knowledge, as throwing light upon the constitution of the fifth and, by analogy, the sixth cycles.

If this second period exists, and fills up the gap between the cerite and platinum groups, the fifth and sixth cycles probably contain three primary septenary series, and the comparison of dimensions between the various successive cycles is as follows :—

Terms of the geometric series a, $a \times b$, $a \times b^2$ . . . $a \times b^n$—

$$10, \tfrac{100}{6}, \tfrac{1000}{36}, \tfrac{10000}{216}, \tfrac{100000}{1296}.$$

The progression between successive alkali metals—

$$16, 16, 3 \times 16, 3 \times 16, 6 \times 16, (6 \times 16).$$

The number of primary septenary series in the cycle—

$$1, 1, 2, 2, (3), (3).$$

The diagram on Plate XXI. shows the dimensions of the fifth and sixth cycles in accordance with the suggestions made in this Paper. The curves of the lower series are the curves of atomic volume, and the curves of the upper series show the melting points of the elements.

NOTE ADDED IN PRESS.—This rule is only an approximation. Strictly speaking, the increments of atomic weight which give the positions of lowest atomic volume are alternately equal to the lateral dimensions of a pair of equal cycles and to the mean lateral dimensions of a pair of adjacent unequal cycles.

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END OF VOL. III.

PROCEEDINGS

OF THE

ROYAL IRISH ACADEMY,

VOL. III., SERIES II.

SCIENCE.

DESCRIPTION OF PLATES.

PLATE 1.

Illustrative of a Paper by Mr. John Blackwall and Rev. O. P. Cambridge "On a List of Spiders Captured in the Seychelles Islands by Professor E. Perceval Wright."

Vide Proceedings R. I. Acad., Vol. 3, Ser. 2, p. 1.

Fig. 1. *Saltieus Wrightii.* Bl., ♀. 1*a*, profile, without legs; 1*b*, genital aperture.

2. ,, *acutus.* Bl., ♂. 2*a*, profile, without legs; 2*b*, genital aperture of ♀; 2*c*, palpus of ♂.

3. ,, *activus.* Bl., ♂. 3*a*, profile, without legs; 3*b*, palpus.

4. ,, *constrictus.* Bl., ♀. 4*a*, profile, without legs.

5. *Lyssomanes pallens.* Bl., ♀. 5*a*, profile, without legs; 5*b*, upper side of forepart of cephalo-thorax, showing the relative size and position of the eyes.

6. *Thomisus insularis.* Bl., ♀. 6*a*, profile, without legs; 6*b*, upper side of forepart of cephalo-thorax, showing the relative size and position of the eyes.

7. *Olios validus.* Bl., ♂. 7*a*, forepart of upper side of cephalo-thorax, showing the relative size and position of the eyes; 7*b*, palpus of ♂; 7*c*, profile of ♂, without legs; 7*d*, genital aperture of ♀.

PLATE 2.

Illustrative of a Paper by Mr. John Blackwall and Rev. O. P. Cambridge "On a List of Spiders Captured in the Seychelles Islands by Professor E. Perceval Wright."

Vide Proceedings R. I. Acad., Vol. 3, Ser. 2, p. 1.

Fig. 8.* *Sparassus guttatus.* Bl., ♀. 8*a*, profile, without legs; 8*b*, forepart of cephalo-thorax, showing the relative size and position of the eyes; 8*c*, maxillæ and labium.

9. *Clubiona nigromaculosa.* Bl., ♀. 9*a*, profile, without legs.

10. *Theridion placens.* Bl., ♂. 10*a*, palpus; 10*b*, profile, without legs.

11. *Argyrodes rostrata.* Bl., ♂. 11*a*, profile, without legs; 11*b*, palpus.

12. *Epeira cognata.* Bl., ♂. 12*a*, profile, without legs; 12*b*, palpus; 12*c*, genital aperture of ♀; 12*d*, ditto, from below.

13. *Nephila plumipes.* C. Koch., ♂. 13*a*, palpus.

14. *Tetragnatha minax.* Bl., ♂. 14*a*, one of the falces; 14*b*, forepart of cephalo-thorax, showing the relative size and position of the eyes; 14*c*, palpus.

15. *Tetragnatha Thorellii.* Bl., ♀. 15*a*, profile, without legs; 15*b*, genital aperture.

* This figure is referred to by mistake, in the description of the Spider, as in Pl. 1.

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AND

MEMBERS

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1882

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Publication, . 2, 3, 5, 6 (*Sec.*), 14, 15, 16, 20.
Library, . . 3, 4, 10, 14, 15 (*Sec.*), 16, 18, 19.
Irish Manuscripts, 6, 7, 9, 12, 13, 14 (*Sec.*), 15, 16, 18.
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1871. June 12	*†Amherst, William Amhurst Tyssen-, D.L., M.P., F.S.A., M.R.S.L. *Didlington Hall, Brandon, Norfolk.*
1873. Jan. 13	Andrews, Arthur, Esq. *Newtown House, Blackrock, Co. Dublin.*
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1870. April 11	†Ardilaun, Right Hon. Arthur, Baron, M.A., D.L. *Ashford, Cong, Co. Galway; St. Anne's, Clontarf, Co. Dublin.*
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1872. June 24	Baldwin, Thomas, Esq. 67, *Pembroke-road, Dublin.*
1840. April 13	*Ball, John, M.A., F.R.S., F.L.S. 10, *Southwell Gardens, South Kensington, London, S.W.*

Date of Election.	
1870. Jan. 10	§Ball, Robert Stawell, LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland. *The Observatory, Dunsink, Co. Dublin.*
1842. Jan. 10	*Banks, John T., M.D., F.K.Q.C.P.I. 45, *Merrion-square, East, Dublin.*
1868. Jan. 13	*Barker, W. Oliver, M.D., M.R.C.S.E. 6, *Gardiner's-row, Dublin.*
1874. May 11	Barrett, William F., F.R.S.E., Professor of Physics, Royal College of Science. 18, *Belgrave-square, N., Monkstown, Co. Dublin.*
1866. May 14	Barrington, Sir John, D.L. *Langhton, Kingstown, Co. Dublin.*
1880. Feb. 9	*†Barry, Michael, M.D. 56, *Ventnor-villas, Brighton.*
1880. Feb. 9	†Barter, Rev. John B. *Rose Hill, Rostellan, Midleton, Co. Cork.*
1879. Feb. 10	*Beaney, James G., M.D. *Melbourne, Australia.*
1878. June 24	†Beattie, Joseph A., L.R.C.S.I. *Mount Blacquiere, Royal Canal, Dublin.*
1865. Jan. 9	*Beauchamp, Robert Henry, Esq. 25, *Fitzwilliam-square, South, Dublin.*
1863. April 27	*Belmore, Right Hon. Somerset Richard, Earl of, M.A., D.L., K.C.M.G. *Castle Coole, Enniskillen.*
1866. June 11	Bennett, Edward Hallaran, M.D., M.Ch., F.R.C.S.I., F.R.G.S.I., Professor of Surgery in the University of Dublin. 26, *Lower Fitzwilliam-street, Dublin.*
1851. June 9	†Beresford, Right Hon. and Most Rev. Marcus G., D.D., D.C.L., Lord Archbishop of Armagh, Primate of all Ireland. *The Palace, Armagh.*
1876. Jan. 10	*Blake, John A., M.P. 2, *Saville-row, London, W.*
1879. Jan. 13	Blake, George Dennis, Esq. *St. Columba, Ballybrack, Co. Dublin.*
1871. Jan. 9	Bourke, Very Rev. (Canon) Ulick J. *Kilcolman, Claremorris.*
1873. April 14	†Boyd, Michael A., F.R.C.S.I., L.K.Q.C.P.I. 90, *Upper George's-street, Kingstown, Co. Dublin.*
1854. April 10	**Brady,* Cheyne, Esq. *(Abroad.)*
1849. April 9	*Brady, Daniel Fredk., F.R.C.S.I., M.R.C.S.E., J.P. *La Choza, Rathgar-road, Co. Dublin.*
1858. April 12	†Brooke, Thomas, D.L. *The Castle, Lough Eske, Co. Donegal.*
1878. May 13	†Browne, John, Esq. *Drapersfield, Cookstown, Co. Tyrone.*
1851. Jan. 13	*Browne, Robert Clayton, M.A., D.L. *Browne's Hill, Carlow.*

Date of Election.

1874. Feb. 9 †Burden, Henry, M.A., M.D., M.R.C.S.E. 8, *Alfred-street, Belfast.*

1854. April 10 Burke, Sir John Bernard (Ulster), LL.D., C.B. *Tullamaine Villa, Upper Leeson-street, Dublin.*

1855. Jan. 8 *Butcher, Richard G., M.D., F.R.C.S.I., M.R.C.S.E. 19, *Lower Fitzwilliam-street, Dublin.*

1866. April 9 Byrne, John A., B.A., M.B. (Dub.) 21, *Merrion-square, North, Dublin.*

1876. May 8 Byrne, William H., C.E., *Sunbury Gardens, Palmerston-park, Rathmines, Co. Dublin.*

1862. April 14 Campbell, John, M.D., Professor of Chemistry C.U.I. 161, *Rathgar-road, Co. Dublin.*

1873. May 12 †Carlingford, Right Hon. Chichester, Baron, K.P., Lord Lieutenant of Essex. *Red House, Ardee;* 7, *Carlton Gardens, London, S.W.*

1838. Feb. 12 *Carson, Rev. Joseph, D.D., S.F.T.C.D., F.R.G.S.I. 18, *Fitzwilliam-place, Dublin.*

1876. Jan. 10 †Carton, Richard Paul, Q.C. 35, *Rutland-square, West, Dublin.*

1866. May 14 §Casey, John, LL.D., F.R.S., Professor of Higher Mathematics and Mathematical Physics, C.U.I., a Vice-President of the Academy. 86, *South Circular-road, Dublin.*

1873. Jan. 13 †Castletown of Upper Ossory, Right Hon. John Wilson, Baron, Lieutenant of the Queen's County. *Lisduff, Errill, Templemore.*

1878. May 13 *Cathcart, George L., M.A., F.T.C.D. 106, *Lower Baggot-street, Dublin.*

1842. June 13 *Chapman, Sir Benjamin J., Bart., D.L. *Killua Castle, Clonmellon.*

1864. Jan. 11 Charlemont, Right Hon. James Molyneux, Earl of, K.P., Lieutenant of the County Tyrone. *Roxborough Castle, Moy, Co. Armagh.*

1876. April 10 *Clarke, Rev. Francis E., M.A., M.D., L.K.Q.C.P.I., M.R.C.S.E. *Killinagh Rectory, Blacklion, Co. Cavan.*

1841. Jan. 11 *†Clermont, Right Hon. Thomas, Baron, D.L. *Ravensdale Park, Newry.*

1867. May 13 *Close, Rev. Maxwell H., M.A., F.R.G.S.I., F.G.S., Treasurer of the Academy. 40, *Lower Baggot-street, Dublin.*

1835. Nov. 30 **Cole,* Owen Blayney, D.L.

1882. Feb. 13 †Collins, Charles MacCarthy, Esq. *Union Bank of Australia, Melbourne.*

1882. Feb. 13 †Comerford, Rev. Michael, P.P. *Monasterevan, Co. Kildare.*

Date of Election.	
1866. April 9	†Cooper, Lieut. Col. Edward H., Lieutenant of Co. Sligo. *Markree Castle, Collooney.*
1856. April 14	Copland, Charles, Esq. *Royal Bank, Foster-place, Dublin;* 7, *Longford-terrace, Monkstown, Co. Dublin.*
1878. June 24	Corbet, William J., M.P. *Springfarm, Delgany.*
1880. Dec. 13	†Corry, Thomas Hughes, M.A. *Benvue, Windsor Park, Belfast.*
1864. May 9	†Cotton, Charles Philip, B.A., C.E., F.R.G.S.I., *Ryecroft, Bray.*
1876. Apr. 10	Cox, Michael Francis, M.A., L.R.C.S.I. 97, *Stephen's-green, South, Dublin.*
1882. Feb. 13	*†Cox, William Sidney, C.E. 66, *George-street, Limerick.*
1857. Aug. 24	*§Crofton, Denis, B.A., 8, *Mountjoy-square, North, Dublin.*
1866. June 11	Cruise, Francis R., M.D., F.K.Q.C.P.I., M.R.C.S.E. 93, *Merrion-square, West, Dublin.*
1870. Apr. 11	Cruise, Richard Joseph, F.R.G.S.I., Geological Survey of Ireland. *Castleisland, Co. Kerry;* 14, *Hume-street, Dublin.*
1876. Nov. 13	*†Dalway, Marriott R., D.L. *Bella Hill, Carrickfergus.*
1853. April 11	*Davies, Francis Robert, K.J.J. *Hawthorn, Carysfort-avenue, Blackrock, Co. Dublin.*
1855. May 14	*§Davy, Edmund W., M.A., M.D., Prof. of Med. Jurisprudence, R.C.S.I. 1, *Fortfield Terrace, Templeogue, Co. Dublin.*
1846. April 13	*D'Arcy, Matthew P., M.A., D.L. 40, *Merrion-square, East, Dublin.*
1876. Jan. 10	Day, Robert, Jun., F.S.A. *Sidney-place, Cork.*
1876. Jan. 10	Deane, Thomas Newenham, R.H.A., F.R.I.A.I. 3, *Upper Merrion-street, Dublin.*
1846. Jan. 12	*Deasy, Right Hon. Rickard, LL.D., Lord Justice of Appeal in Ireland. *Carysfort House, Blackrock, Co. Dublin.*
1860. Jan. 9	*Dickson, Rev. Benjamin, D.D., F.T.C.D. 3, *Kildare-place, Dublin.*
1876. Feb. 14	Dillon, William, Esq. 2, *North Great George's-street, Dublin.*
1876. Jan. 10	*§Doberck, William, Ph.D. *Observatory, Markree, Collooney.*
1851. Jan. 13	*Dobbin, Rev. Orlando T., B.D., LL.D. *St. George's-terrace, Gravesend, London.*
1879. June 9	*Doherty, William J., C.E. *Clonturk House, Drumcondra, Co. Dublin.*

Date of Election.	
1876. June 26	§Draper, Harry N., F.C.S. *Esterel, Temple-road, Upper Rathmines, Co. Dublin.*
1843. Jan. 9	*Drury, William Vallancey, M.D. *Bournemouth.*
1861. Feb. 11	Duncan, James Foulis, M.D., F.K.Q.C.P.I. 8, *Upper Merrion-street, Dublin.*
1867. Feb. 11	Ellis, George, M.B., F.R.C.S.I. 91, *Lower Leeson-street, Dublin.*
1841. April 12	*Emly, Right Hon. William, Baron, Lieutenant of the County Limerick. *Tervoe, Limerick; Athenæum Club, London, S.W.*
1846. Jan. 12	*Enniskillen, Right. Hon. William Willoughby, Earl of, LL.D., D.C.L., D.L., F.R.S., F.R.G.S.I., one of the Trustees of the Hunterian Museum, R.C.S., London. *Florence Court, Co. Fermanagh; 65, Eaton-place, London, S.W.*
1867. April 8	*Farrell, Thomas A., M.A. Care of Messrs. Kelly and Co., *Lower Gardiner-street, Dublin.*
1834. Mar. 15	*§Ferguson, Sir Samuel, LL.D., Q.C., President of the Academy. 20, *North Great George's-street, Dublin.*
1842. Jan. 10	*Ferrier, Alexander, Esq. *Knockmaroon Lodge, Chapelizod, Co. Dublin.*
1878. Feb. 11	Fitzgerald, George F., M.A., F.T.C.D. 40, *Trinity College, Dublin.*
1857. Aug. 24	Fitzgerald, Right Rev. William, D.D., Lord Bishop of Killaloe, &c. *Clarisford House, Killaloe.*
1870. May 23	†FitzGibbon, Abraham, M.I.C.E. Lond. *The Rookery, Great Stanmore, Middlesex.*
1841. April 12	*Fitzgibbon, Gerald, M.A., late Master in Chancery. 10, *Merrion-square, North, Dublin.*
1875. Jan. 11	Fitzpatrick, William John, LL.D., J.P. 49, *Fitzwilliam-square, West, Dublin.*
1881. Jan. 10	Fletcher, Joseph, F.C.SS., London and Berlin. *Gilford House, Sandymount, Co. Dublin.*
1860. Jan. 9	Foley, William, M.D., M.R.C.S.E. *Kilrush.*
1874. Feb. 9	†Foster, Rev. Nicholas. *Ballymacelligott Rectory, Tralee.*
1876. Feb. 14	Fottrell, George, Esq. 8, *North Great George's-street, Dublin.*
1838. Nov. 12	**Frazer*, George A., Captain R.N.
1866. May 14	Frazer, William, F.R.C.S.I., F.R.G.S.I. 20, *Harcourt-street, Dublin.*

Date of Election.	
1865. April 10	†Freeland, John, M.D. *Antigua, West Indies.*
1881. June 13	†Freeman, D.J., M.R.I.A.I. 34, *Dawson-street, Dublin.*
1847. May 10	*Freke, Henry, M.D. (Dub.), F.K.Q.C.P.I. 68, *Lower Mount-street, Dublin.*
1873. April 14	*†Frost, James, J.P. *Ballymorris, Cratloe, Co. Clare.*
1875. June 14	Furlong, Nicholas, M.D. *Symington, Enniscorthy.*
1859. Jan. 10	Gages, Alphonse, Chev. L.H., F.R.G.S.I. *Royal College of Science*, 51, *Stephen's-green, East, Dublin.*
1845. April 4	*Galbraith, Rev. Joseph Allen, M.A., S.F.T.C.D., F.R.G.S.I. 8, *Trinity College;* 46, *Lansdowne-road, Dublin.*
1878. May 13	Galloway, Robert, F.C.S. 47, *Leeson-park, Dublin.*
1880. June 28	Gannon, John Patrick, Esq. *Laragh, Maynooth.*
1864. Jan. 11	*Garnett*, George Charles Lionel, M.A.
1863. Feb. 9	*Garstin, John Ribton, M.A., LL.B., F.S.A., F.R. Hist. Soc., Hon. F.R.I.A.I., J.P. *Braganstown, Castlebellingham, Co. Louth; Green-hill, Killiney, Co. Dublin.*
1855. April 9	*Gilbert, John Thomas, F.S.A., R.H.A., Librarian of the Academy. *Villa Nova, Blackrock, Co. Dublin.*
1876. May 8	Gillespie, William, Esq. *Racefield House, Kingstown. Co. Dublin.*
1875. April 12	*Gore, J. E., C.E., A.I.C.E., F.R.A.S., F.R.G.S.I. *Beltra, Ballisodare, Co. Sligo.*
1836. May 25	*Gough, Right Hon. George S., Viscount, M.A., D.L., F.L.S., F.G.S. *St. Helen's, Booterstown, Co. Dublin.*
1848. June 12	*Graham, Andrew, Esq. *Observatory, Cambridge.*
1848. April 10	*Graham, Rev. William, D.D. *Bonn.*
1876. April 10	†Grainger, Rev. John (Canon), D.D. *Broughshane, Co. Antrim.*
1863. April 13	†Granard, Right Hon. George Arthur Hastings, Earl of, K.P. *Castle Forbes, Co. Longford.*
1837. April 24	*§Graves, Right Rev. Charles, D.D., F.R.S., Lord Bishop of Limerick, &c. *The Palace, Henry-street, Limerick.*
1874. Feb. 9	Gray, William, Esq. 6, *Mount-Charles, Belfast.*
1867. April 8	Green, James S., Q.C. 83, *Lower Leeson-street, Dublin.*
1872. April 8	†Greene, John Ball, C.B., C.E., F.R.G.S.I., Commissioner of Valuation. 6, *Ely-place, Dublin.*
1857. June 8	*Griott, Daniel G., M.A. 9, *Henrietta-street, Dublin.*

Date of Election.	
1873. Dec. 8	*Guinness, Edward Cecil, M.A., D.L. 80, *Stephen's-green, South, Dublin.*
1875. Jan. 11	Hamilton, Edward, M.D., F.R.C.S.I. 120, *Stephen's-green, West, Dublin.*
1879. Dec. 8	Hamilton, Edwin, M.A. 40, *York-street, Dublin.*
1847. Jan. 11	Hancock, William Neilson, Q.C., LL.D. 64B, *Upper Gardiner-street, Dublin.*
1837. Feb. 13	*§Hart, Andrew Searle, LL.D., Vice-Provost of T.C.D. 14, *Lower Pembroke-street; Trinity College, Dublin.*
1861. May 13	Hatchell, John, M.A., J.P. *Forfield House, Terenure, County Dublin.*
1845. Feb. 24	*§Haughton, Rev. Samuel, M.A., M.D., D.C.L. (Oxon.), LL.D. (Cantab.), F.R.S., F.G.S., F.R.G.S.I., F.K.Q.C.P.I., Hon. F.R.C.S.I., S.F.T.C.D., a Vice-President of the Academy. 31, *Upper Baggot-street, Dublin.*
1852. April 12	*Head, Henry H., M.D., F.K.Q.C.P.I., F.R.C.S.I., F.R.G.S.I. 7, *Fitzwilliam-square, East, Dublin.*
1870. April 11	†Heily, John Vickers, M.D. *Lisaduran Cottage, Rushworth, Melbourne, Victoria.*
1840. June 8	*Hemans, George Willoughby, C.E., F.G.S. 1, *Westminster Chambers, Victoria-street, London, S.W.*
1851. Jan. 13	*§Hennessy, Henry, F.R.S., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland, Stephen's-green, Dublin. *Brookvale House, Donnybrook, Co. Dublin.*
1865. Feb. 13	*Hennessy, William Maunsell, Esq. 71, *Pembroke-road, Dublin.*
1873. Jan. 13	Hickie, James Francis, Lieut.-Col. (retired), J.P. *Slevoir, Roscrea, Co. Tipperary.*
1867. Feb. 11	†Hill, John, C.E., F.R.G.S.I. *County Surveyor's Office, Ennis.*
1875. Jan. 11	*Hill, Arthur, B.E., A.R.I.B.A. 22, *George's-street, Cork.*
1881. May 9	†Hillis, John David, M.D., F.R.C.S.I. *Demerara, West Indies.*
1824. Feb. 28	*Hudson, Henry, M.D., F.K.Q.C.P.I. *Glenville, Fermoy.*
1875. June 14	†Hume Rev. Abraham, (Canon), D.C.L., LL.D. (Hon.); F.S.A.; F.R.S.N.A. (Copenhagen); Corr. F.S.A. Scot.; Hon. F.S.A. Newcastle; Member of the Philological and Eng. Dialect Societies; Ex-President Historic Soc. of Lanc. and Cheshire. *All Souls' Vicarage, Liverpool.*

Date of Election.	
1866. June 11	Hutton, Thomas Maxwell, J.P. 118, *Summerhill, Dublin.*
1847. Jan. 11	*Ingram, John Kells, LL.D., F.T.C.D., Librarian of Trinity College, Dublin, a Vice-President of the Academy. 2, *Wellington-road, Dublin.*
1879. April 14	†Ingram, Thomas Dunbar, LL.D. 13, *Wellington-road, Dublin.*
1841. April 12	*§Jellett, Rev. John Hewitt, D.D., F.R.G.S.I. Provost of Trinity College, Dublin, Royal Medalist R.S., 1881. *Provost's House, Trinity College, Dublin.*
1842. June 13	*Jennings, Francis M., F.G.S., F.R.G.S.I. *Brown-street, Cork.*
1867. April 8	Jephson, Robert H., Esq. 30, *Lansdowne-road, Dublin.*
1881. May 9	Jeremy, Rev. Daniel Davis, M.A. 4, *Appian Way, Dublin.*
1863. Jan. 12	Joyce, Patrick Weston, LL.D. *Lyre na Grena, Leinster-road, Rathmines, Co. Dublin.*
1870. Dec. 12	*†Joyce, Robert D., M.D. 21, *Bowdoin-street, Boston, Mass., U.S., America.*
1878. May 13	*Kane, John F., Esq. *Leeson-park House, Dublin.*
1831. Nov. 30	*§Kane, Sir Robert, M.D., LL.D., F.K.Q.C.P.I., F.R.S., F.R.G.S.I., F.C.S., Royal Medalist R.S., 1841. *Fortlands, Killiney, Co. Dublin.*
1873. Dec. 8	*Kane, Robert Romney, M.A. *Dungiven, Ailesbury-road, Dublin.*
1865. April 10	Kane, William Francis De Vismes, M.A., J.P. *Sloperton Lodge, Kingstown; Drumreaske House, Monaghan.*
1870. June 13	*Keane, John P., C.E., Engineer, Public Works Department, Bengal. *Calcutta.*
1867. Feb. 11	Keane, Marcus, J.P. *Beech Park, Ennis.*
1864. Nov. 14	*Keenan, Sir Patrick J., C.B., K.C.M.G., Resident Commissioner, Board of National Education, Ireland. *Delville, Glasnevin, Co. Dublin.*
1876. May 8	Kelly, James Edward, M.D. 13, *Rutland-square, East, Dublin.*
1870. May 23	*Kelly, John, L.M. (Dub.). *University College Hospital, Calcutta.*
1846. April 13	*Kennedy, James Birch, J.P. *Cara, by Killarney.*
1874. May 11	†Kidd, Abraham, M.D. *Ballymena.*
1876. Feb. 14	*†Kildare, Most Hon. Gerald, Marquess of. *Carton, Maynooth.*

Date of Election.

1875. June 14 †Kilgarriff, Malachy J., F.R.C.S.I. 30, *Harcourt-street, Dublin.*

1866. April 9 *Kinahan, Edward Hudson, J.P. 11, *Merrion-square, North, Dublin.*

1868. Jan. 13 Kinahan, George Henry, F.R.G.S.I., Geological Survey of Ireland, *Ovoca, Co. Wicklow;* 14, *Hume-street, Dublin.*

1863. April 13 Kinahan, Thomas W., M.A. 24, *Waterloo-road, Dublin.*

1845. June 8 *King, Charles Croker, M.D., F.R.C.S.I, Medical Commissioner, Local Government Board. 34, *Upper Fitzwilliam-street, Dublin.*

1837. Feb. 13 *§*Knox*, George J., Esq.

1864. April 11 *Lalor, John J., F.R.G.S.I. *City Hall, Cork-hill, Dublin.*

1875. May 10 †Lane, Alexander, M.D. *Ballymoney.*

1864. Jan. 11 LaTouche, J. J. Digges, M.A. 1, *Ely-place, Upper, Dublin.*

1836. Jan. 25 *LaTouche, William Digges, M.A., D.L. 34, *Stephen's-green, North, Dublin.*

1857. May 11 *Lawson, Right Hon. James A., LL.D., Justice of the Court of Common Pleas. 27, *Upper Fitzwilliam-street, Dublin.*

1857. April 13 *Leach, Lieut.-Colonel George A., R.E. 3, *St. James's-square, London, S.W.*

1845. Feb. 10 *LeFanu, William R., C.E. *Summerhill, Enniskerry, Co. Wicklow.*

1846. May 11 **Lefroy*, George, Esq. *(Abroad.)*

1844. April 8 *†Leinster, His Grace Charles William, Duke of, President of the Royal Dublin Society. *Carton, Maynooth.*

1869. April 12 *Lenihan, Maurice, J.P. *Limerick.*

1853. April 11 Lentaigne, Sir John, C.B.. M.B., J.P., F.R.G.S.I. 1, *Great Denmark-street, Dublin.*

1870. June 13 Leonard, Hugh, F.G.S., F.R.G.S.I., Geological Survey of Ireland. *St. David's, Malahide-road, Dublin.*

1868. April 27 *Little, James, M.D., L.R.C.S.I., F.K.Q.C.P.I. 14, *Stephen's-green, North, Dublin.*

1876. Jan. 10 Lloyd, Joseph Henry, M.A., LL.D., Ph. D., F.R.S.L., F.S.A., M. Phil. Soc. 7, *Lower Gardiner-street, Dublin.*

1846. Jan. 12 **Lloyd*, William T., M.D.

1875. April 12 Lombard, James F., J.P. *South-hill, Rathmines, Co. Dublin.*

Date of Election.	
1838. Feb. 12	*Longfield, Right Hon. Mountifort, LL.D. (late Judge in the Landed Estates' Court). 47, *Fitzwilliam-square, West, Dublin.*
1878. Feb. 11	*†Lowry, Robert William, B.A. (Oxon.) D.L., J.P. *Pomeroy House, Dungannon, Co. Tyrone.*
1868. Jan. 13	Lyne, Robert Edwin, Esq. 2, *Hargrave-terrace, Terenure-road, Rathgar, Co. Dublin.*
1851. May 12	*Lyons, Robert D., M.B., F.K.Q.C.P.I., M.P., Prof. of Medicine, C.U.I. 88, *Merrion-square, West, Dublin.*
1873. April 14	§Macalister, Alexander, M.D., F.R.S., L.R.C.S.I, L.K.Q.C.P.I., F.R.G.S.I., Professor of Anatomy and Comparative Anatomy in the University of Dublin, Secretary of the Academy. 11, *Upper Fitzwilliam-street, Dublin.*
1871. Feb. 13	*Macartney, J. W. Ellison, M.P., J.P. *The Palace, Clogher.*
1875. Jan. 11	†MacCarthy, John G., Esq. *River View, Montenotte, Cork.*
1881. June 27	†McClintock, Rev. Francis Le Poer, M.A. (Cantab.), *Spencer Hill, Castlebellingham, Co. Louth.*
1874. Feb. 9	McClure, Rev. Edmund, M.A. *Society for Promoting Christian Knowledge, Northumberland-avenue, Charing Cross, London, S.W.*
1873. Jan. 13	*McCready, Rev. Christopher, M.A. 56, *High-street, Dublin.*
1864. April 11	*McDonnell, Alexander, M.A., C.E., F.R.G.S.I. *St. John's, Island-bridge, Co. Dublin.*
1845. Feb. 24	**Macdonnell*, James S., C.E.
1827. Mar. 16	*MacDonnell, John, M.D., F.R.C.S.I., F.R.G.S.I. 32, *Upper Fitzwilliam-street, Dublin.*
1857. Feb. 9	*§McDonnell, Robert, M.D., F.R.C.S.I., F.R.S. 89, *Merrion-square, West, Dublin.*
1865. April 10	†Mac Donnell, Lieut.-Col. William Edward Armstrong, Vice-Lieutenant of the County Clare. *New Hall, near Ennis.*
1882. Feb. 13	McHenry, Alexander, Esq., Geological Survey of Ireland. 6, *Ashford-terrace, Ball's Bridge, Dublin.*
1856. June 9	*†Mac Ivor, Rev. James, D.D., F.R.G.S.I. *Moyle, Newtownstewart.*
1876. April 10	MacIlwaine, Rev. William (Canon), D.D. *Ulsterville, Belfast.*
1881. Feb. 14	§Mackintosh, Henry William, M.A., Professor of Zoology in the University of Dublin. *Trinity College, Dublin.*
1871. April 10	Macnaghten, Colonel Sir Francis Edmund, Bart. (Late 8th Hussars), Vice-Lieutenant of the Co. Antrim. *Dundarave, Bushmills, Co. Antrim.*

Date of Election.	
1874. April 13	MacSwiney, Stephen Myles, M.D. 38, *York-street, Dublin.*
1846. Feb. 23	*Madden, Richard R., F.R.C.S. Eng. 1, *Vernon-terrace, Booterstown-avenue, Booterstown, Co. Dublin.*
1864. June 13	Madden, Thomas More, M.D., L.K.Q.C.P.I., M.R.C.S.E. 55, *Merrion-square, South, Dublin.*
1882. April 10	†Mahony, Richard John, B.A. (Oxon.) D.L. *Dromore Castle, Kenmare, Co. Kerry.*
1880. May 10	†Mahony, William Aloysius, L.K.Q.C.P.I., L.R.C.S. Edin. *Mitchelstown, Co. Cork.*
1874. Feb. 9	§Malet, John Christian, M.A., Professor of Mathematics. *Queen's College, Cork.*
1865. April 10	*Malone, Rev. Silvester, P.P., F.R.H.A.A.I. *Six-milebridge, Co. Clare.*
1859. Jan. 10	*†Manchester, His Grace William Drogo, Duke of. 1, *Great Stanhope-street, London; Kimbolton Castle, St. Neot's, Hunts; The Castle, Tanderagee.*
1871. Jan. 9	Maunsell, George Woods, M.A., D.L., Vice-President, Royal Dublin Society. 78, *Merrion-square, South, Dublin.*
1879. Feb. 10	Meldon, Austin, M.D. 15, *Merrion-square, North, Dublin.*
1861. Jan. 14	†Monck, Right Hon. Charles Stanley, Viscount, G.C.M.G., Lieutenant of Dublin City and County. *Charleville, Bray, Co. Wicklow.*
1858. Jan. 11	**Montgomery*, Howard B., M.D.
1860. Jan. 9	Moore, Alexander G. Montgomery, Colonel, Assistant Adjutant-General. *Royal Hospital, Kilmainham.*
1861. Jan. 14	Moore, James, M.D., M.R.C.S.E. 7, *Chichester-street, Belfast.*
1869. Feb. 8	*Moran, Most Rev. Patrick F., D.D., Bishop of Ossory. *St. Kyran's College, Kilkenny.*
1866. April 9	More, Alexander Goodman, F.L.S., Soc. Zoo. Bot. Vindob. Socius, Director of the Natural History Museum, Science and Art Department, Leinster House. 92, *Leinster-road, Rathmines, Co. Dublin.*
1874. Feb. 9	§Moss, Richard J., F.C.S., Keeper of the Minerals, Museum of Science and Art. 66, *Kenilworth-square, Rathgar.*
1876. April 10	†Myers, Walter, Esq. 2, *Richard-street, Spencer-street, Birmingham.*
1840 Feb. 10	*Napier, Right Hon. Sir Joseph, Bart., D.C.L., LL.D., *University Club, Dublin.*
1844. June 8	*Neville, John, C.E., F.R.G.S.I. *Roden-place, Dundalk.*

Date of Election.	
1854. May 8	Neville, Parke, C.E. 58, *Pembroke-road, Dublin.*
1873. Jan. 13	Nolan, Joseph, F.R.G.S.I., Geological Survey of Ireland. 47, *Great James's-street, Derry;* 14, *Hume-street, Dublin.*
1846. Jan. 12	*†Nugent, Arthur R., Esq. *(Portaferry, Co. Down.)*
1869. June 14	*O'Brien, James H., Esq. *St. Lorcan's, Howth, Co. Dublin.*
1875. Jan. 11	O'Callaghan, J. J., F.R.I.A.I. 31, *Harcourt-street, Dublin.*
1867. June 10	O'Conor Don, The, D.L. *Clonalis, Castlerea, Co. Roscommon.*
1867. Jan. 14	O'Donel, Charles J., J.P. 47, *Lower Leeson-street, Dublin.*
1865. Apr. 10	O'Donnavan, William J., LL.D. *University Club,* 17, *Stephen's-green, North, Dublin;* 79, *Kenilworth-square, Rathgar, Co. Dublin.*
1869. Apr. 12	†O'Ferrall, Ambrose More, J.P. *Balyna House, Enfield, Co. Kildare.*
1882. Apr. 10	†O'Farrell, Francis J., F.C.S. *The Manor House, Dundrum.*
1866. Jan. 8	*O'Grady, Edward S., B.A., M.B., M. Ch., F.R.C.S.I. 105, *Stephen's-green, South, Dublin.*
1867. May 13	†O'Grady, Standish H., Esq. *Erinagh House, Castleconnell;* 2, *Southampton-st., Strand, London, W.C.*
1866. June 25	O'Hagan, Hon. John, M.A., Judge of the Supreme Court of Judicature in Ireland, and Judicial Commissioner Irish Land Commission. 22, *Upper Fitzwilliam-street, Dublin.*
1857. June 8	O'Hagan, Right Hon. Thomas, Baron, K.P. *Woodlands, Clonsilla, Co. Dublin.*
1869. Apr. 12	O'Hanlon, Very Rev. John, P.P. *Sandymount, Co. Dublin.*
1878. Feb. 11	O'Hanlon, Michael, L.K.Q.C.P.I. *Castlecomer, Co. Kilkenny.*
1866. Jan. 8	O'Kelly, Joseph, M.A., F.R.G.S.I., Geological Survey of Ireland. 72, *Eccles-street, Dublin;* 14, *Hume-street, Dublin.*
1869. Apr. 12	O'Laverty, Rev. James, P.P. *Holywood, near Belfast.*
1876. Feb. 14	Olden, Rev. Thomas, B.A. *Ballyclough, Mallow, Co. Cork.*
1871. Apr. 10	O'Looney, Brian, F.R.H.S., Professor of Irish Language, Literature, and Archæology to the Catholic University of Ireland, *Grove-villa House, Crumlin, Co. Dublin.*
1861. June 10	*O'Mahony, Rev. Thaddeus, D.D. *Trinity College, Dublin.*

Date of Election.

1870. Jan. 10 §O'Reilly, Joseph P., C.E., Prof. of Mining and Mineralogy, Royal College of Science, Dublin, Secretary of Foreign Correspondence of the Academy. 58, *Park-avenue, Sandymount, Co. Dublin.*

1878. May 13 O'Reilly, Rev. John, C.C. 13, *North Richmond-street, Dublin.*

1879. May 12 †O'Rorke, Very Rev. Terence, D.D., P.P. *Collooney, Sligo.*

1866. June 11 O'Rourke, Very Rev. (Canon) John, P.P. *St. Mary's, Maynooth.*

1838. Dec. 10 *Orpen, John Herbert, LL.D. 58, *Stephen's-green, East, Dublin.*

1870. Feb. 14 O'Shaughnessy, Mark S., LL.D., F.R.S.L., Regius Prof. of English Law, Queen's College, Cork. 27, *St. Patrick's-hill, Cork.*

1866. Jan. 8 O'Sullivan, Daniel, Ph. D. *Rosemount, North Circular-road, Dublin.*

1839. June 10 *Parker, Alexander, J.P. 46, *Upper Rathmines, Co. Dublin.*

1873. Feb. 10. Patterson, William Hugh, Esq., *Garranard, Strandtown, Belfast.*

1847. Feb. 8 *†Pereira [elected as Tibbs], Rev. Henry Wall, M.A., F.S.A. Scot., &c. *Sutton Wick, Abingdon.*

1872. Apr. 8 Phayre, Major-General Sir Arthur Purves, K.C.S.I., G.C.M.G., C.B. *Bray, Co. Wicklow.*

1863. Apr. 13 Pigot, David R., M.A., Master, Court of Exchequer. 12, *Leeson-park, Dublin.*

1870. Apr. 11 Pigot, Thomas F., C.E., Prof. of Descriptive Geometry, etc., Royal College of Science, Dublin. 4, *Wellington-road, Dublin.*

1838. Feb. 12 *Pim, George, J.P. *Brennanstown, Cabinteely, Co. Dublin.*

1849. Jan. 8 *Pim, Jonathan, Esq. *Greenbank, Monkstown, Co. Dublin.*

1880. Feb. 9 Plunkett, Thomas, F.R.G.S.I. *Enniskillen.*

1864. Jan. 11 *†*Poore*, Major Robert, (Late 8th Hussars). *(Abroad.)*

1862. Apr. 14 *Porte, George, Esq. 43, *Great Brunswick-st., Dublin.*

1873. Jan. 13 *Porter, Alexander, M.D., F.R.C.S., Assist.-Surgeon, Indian Army. *Madras.*

1875. Jan. 11 †Porter, George Hornidge, M.D., Surgeon in Ordinary to the Queen in Ireland, M. Ch. 3, *Merrion-square, North, Dublin.*

1852. Apr. 12 **Porter*, Henry J. Ker, Esq.

1873. Jan. 13 Powell, George Denniston, M.D., L.R.C.S.I. 76, *Upper Leeson-street, Dublin.*

1864. June 13 †Power, Sir Alfred, K.C.B., M.A. 35, *Raglan-road, Dublin.*

Date of Election.	
1875. April 12	*†Powerscourt, Right Hon. Mervyn Wingfield, Viscount. *Powerscourt, Enniskerry, Bray.*
1854. Jan. 9	Pratt, James Butler, C.E. *Drumsna, Co. Leitrim.*
1874. Dec. 14	*†Purcell, Mathew John, Esq. *Burton Park, Churchtown, Co. Cork; Stephen's-green Club, Dublin.*
1858. Jan. 11	Purser, John, M.A., D.Sc., Professor of Mathematics. *Queen's College, Belfast.*
1881. Apr. 11	*Quinlan, Francis John Boxwell, B.A., M.D., F.K.Q.C.P.I. 29, *Lower Fitzwilliam-street, Dublin.*
1867. Jan. 14	*†Read, John M., General, U.S.; Consul-General of the U.S.A. for France and Algeria, Member of American Philos. Soc., Fellow of the Royal Soc. of Northern Antiquaries, &c. *Athens.*
1846. Dec. 14	*§Reeves, Very Rev. William, D.D., M.B., LL.D., Dean of Armagh, a Vice-President of Academy. *The Public Library, Armagh; Rectory, Tynan.*
1843. Feb. 13	*§*Renny*, Henry L., F.R.G.S.I., Lieut. R.E., (Retired List). [*Quebec ?*]
1878. June 24	*Reynell, Rev. William A., B.D. 8, *Henrietta-street, Dublin.*
1875. Jan. 11	Reynolds, James Emerson, M.D., F.R.S., Professor of Chemistry in the University of Dublin. 62, *Morehampton-road, Donnybrook, Co. Dublin.*
1867. Apr. 8	Richey, Alexander George, LL.D., Q.C. 27, *Upper Pembroke-street, Dublin.*
1875. June 14	Robertson, John C., L.K.Q.C.P.I., M.R.C.S.L., F.R.A.S. *The Asylum, Monaghan.*
1881. Jan. 10	Robinson, John L., C.E., M.R.I.A.I. 48, *Clarinda-park, East, Kingstown, Co. Dublin.*
1844. June 10	*Roe, Henry, M.A. *(Isle of Man.)*
1876. Jan. 10	*†Ross, Rev. William. *Chapel Hill House, Rothesay.*
1870. Nov. 30	Rosse, Rt. Hon. Lawrence, Earl of, D.C.L., D.L., F.R.S., F.R.A.S. *Birr Castle, Parsonstown.*
1872. Apr. 8	Rowley, Standish G., LL.D., J.P., M.R.S.L. *Sylvan-park, Kells, Co. Meath.*
1843. Jan. 9	*§Salmon, Rev. George, D.D., D.C.L. (Oxon.), LL.D. (Cantab.), F.R.S., and Royal Medalist, 1868, Regius Professor of Divinity in the University of Dublin. 81, *Wellington-road, Dublin.*
1853. Jan. 10	*Sanders, Gilbert, Esq. *Albany Grove, Monkstown, County Dublin.*
1851. May 12	*Sayers, Rev. Johnston Bridges, LL.D. *Velore, Madras.*
1846. Feb. 9	*†Sherrard, James Corry, Esq. 7, *Oxford-square, Hyde-park, London.*

Date of Election.	
1873. Jan. 13	*†Shirley, Evelyn Philip, M.A., D.L., F.S.A. *Lough Fea, Carrickmacross; Ettington Park, Stratford-on-Avon.*
1869. Apr. 12	Sigerson, George, M.D., M.Ch., F.L.S., Prof. of Botany, C.U.I. 3, *Clare-street, Dublin.*
1835. Feb. 23	*§Smith, Aquilla, M.D., F.K.Q.C.P.I. 121, *Lower Baggot-street, Dublin.*
1877. Dec. 10	*†Smith, Charles, Esq. *Barrow-in-Furness.*
1868. Jan. 13	†Smith, John Chaloner, C.E. *Engineer's Office, Dublin, Wicklow and Wexford Railway, Bray.*
1833. Apr. 22	*Smith, Joseph Huband, M.A.
1876. June 26	Smith, Rev. Richard Travers, (Canon) B.D. *The Vicarage, Clyde-road, Dublin.*
1873. Jan. 13	Smyth, Patrick James, M.P., Chev. L. H. 15, *Belgrave-square, East, Rathmines, Co. Dublin.*
1867. Jan. 14	Smythe, William Barlow, M.A., D.L. *Barbavilla House, Collinstown, Killucan.*
1873. April 14	*Smythe, William James, Lieutenant-General, R.A., F.R.S. *Coole Glebe, Carnmoney, Belfast.*
1874. Dec. 14	Stewart, James, M.A. (Cantab.), Professor of Greek and Latin, C.U.I. 21, *Gardiner's-place, Dublin.*
1871. June 12	§Stokes, Hon. Whitley, LL.D., C.S.I., Member of the Supreme Council of India. *Legislative Council House, Calcutta.*
1874. June 22	Stokes, William, M.D., M. Ch. 5, *Merrion-square, North, Dublin.*
1857. June 8	*§Stoney, Bindon B., M.A., C.E., F.R.S., F.R.G.S.I. 14, *Elgin-road, Dublin.*
1856. Apr. 14	§Stoney, George Johnstone, M.A., D.Sc., F.R.S., 3, *Palmerston-park, Upper Rathmines.*
1857. Aug. 24	*Sullivan, William Kirby, Ph.D., President of Queen's College, Cork. *Queen's College, Cork.*
1874 Apr. 13	†Sweetman, H. S., Esq. 38, *Alexandra-road, St. John's Wood, London, N.W.*
1845. Feb. 24	*Sweetman, Walter, J.P. 4, *Mountjoy-square, North, Dublin.*
1871. Jan. 9	†Symons, John, Esq. 72, *Queen-street, Hull.*
1845 June 23	*Talbot de Malahide, Right Hon. James, Baron, D.C.L., D.L., F.R.S., F.S.A., F.G.S., F.R.G.S.I., F.R. Hist. Soc., Pres. Archæol. Inst. *The Castle, Malahide, Co. Dublin.*
1877. April 9	§Tarleton, Francis Alexander, LL.D., F.T.C.D. 24, *Upper Leeson-street, Dublin.*
1869. Apr. 12	§Tichborne, Charles Roger C., Ph.D., F.C.S. 15, *North Great George's-street, Dublin; Apothecaries' Hall*, 40, *Mary-street, Dublin.*

Date of Election.	
1864. Mar. 16	Trench, Right Hon. and Most Rev. Richard Chenevix, D.D., Lord Archbishop of Dublin, Primate of Ireland. *The Palace, Stephen's-green, North, Dublin.*
1879. June 9	*†Tucker, Stephen Isaacson, Esq., Somerset Herald, *Heralds' College, London, E.C.*
1846. Feb. 9	*Tuffnell, Thomas Joliffe, F.R.C.S.I., M.R.C.S.E. 58, *Lower Mount-street, Dublin.*
1871. June 12	†Tyrrell, Colonel Frederick, J.P. *Gold Coast Colony, Acera, care of Forbes & Co.*, 25, *Cockspur-street, London, S.W.*
1876. April 10	*†Tyrrell, George Gerald, Esq., Clerk of the Crown, Co. Armagh. 30, *Upper Pembroke-street, Dublin; Banbridge, Co. Down.*
1870. Nov. 30	†Ventry, Right Hon. Dayrolles Blakeney, Baron, D.L. *Burnham-house, Dingle, Co. Kerry.*
1880. Feb. 9	†Vesey, Agmondisham B., L.K.Q.C.P.I. *Bellevue, Magherafelt.*
1881. Feb. 14	*Ward, Francis Davis, J.P., *Clonaver, Strandtown, Belfast.*
1864. Feb. 8	*†Warren, James W., M.A. 39, *Rutland-square, West, Dublin.*
1881. Jan. 10	*†Watts, Robert George, M.D., F.R.S.L., 5, *Bulstrode-street, Cavendish-square, London, W.*
1866. Apr. 9	Westropp, W. H. Stacpoole, L.R.C.S.I., F.R.G.S.I., &c. *Lisdoonvarna, Co. Clare.*
1876. Nov. 13	†White, Rev. Hill Wilson, LL.D., *Wilson's Hospital, Multifarnham, Co. Westmeath.*
1880. Feb. 9	*†White, John Newsom, Esq. *Rocklands, Waterford.*
1857. June 8	*†Whitehead, James, M.D., F.R.C.S.E., M.R.C. Phys., Lon. 87, *Mosley-street, Manchester.*
1851. Jan. 13	*†Whittle, Ewing, M.D., M.R.C.S.E. 1, *Parliament-terrace, Liverpool.*
1874. June 8	Wigham, John R., Esq. 35, *Capel-street, Dublin.*
1873. April 14	Wilkinson, Thomas, Esq. *Enniscorthy, Co. Wexford.*
1839. Jan. 14	*Williams, Richard Palmer, F.R.G.S.I. 38, *Dame-street., Dublin.*
1837. Jan. 9	*Williams, Thomas, Esq. 38, *Dame-street, Dublin.*
1877. April 9	Williamson, Benjamin, M.A., F.R.S., F.T.C.D. 1B, *Dartmouth-road, Dublin.*
1857. Aug. 24	*§Wright, Edward Perceval, M.A., M.D., F.L.S., F.R.C.S.I., J.P., Professor of Botany and Keeper of the Herbarium, Dublin University. 5, *Trinity College, Dublin.*

HONORARY MEMBERS.

Date of Election.	
1863. June 22	His Royal Highness Albert Edward, Prince of Wales.

"*The* President of the Royal Society, and Ex-Presidents *of the same, are always considered Honorary Members of the Academy.*"—By-Laws, ii., 14.

1869. Mar. 16 (Elected Hon. Mem. in Sec. of Science originally.)	Hooker, Sir Joseph Dalton, M.D., K.C.B., F.R.S., D.C.L., LL.D., V-P.L.S., F.G.S., Director of the Royal Gardens, Kew, Ex-President of the Royal Society. *Kew, London, W.*
1863. Mar. 16	Sabine, General Sir Edward, R.A., K.C.B., D.C.L., LL.D., V.P. and Ex-President of the Royal Society, Hon. F.R.S., Edin., F.R.A.S., F.L.S., &c. 13, *Ashley-place, Westminster, London, S.W.*
1832. Nov. 30 (Elected Hon. Mem. in Sec. of Science originally.)	Airy, Sir George Biddell, K.C B., D.C.L., LL.D., Ex-President of the Royal Society (1871), V-P. R.A.S., &c. *Playford, near Ipswich.*
1880. Mar. 16	Spottiswoode, William, M.A., D.C.L., LL.D., President of the Royal Society. 41, *Grosvenor-place, London, S.W.*

SECTION OF SCIENCE.

[Limited to 30 Members, of whom one-half at least must be foreigners.]

1873. Mar. 15	Adams, John Couch, LL.D. (Dub.), F.R.S. and Copley Medalist, V-P.R.A.S., F.C.P.S., etc., Director of the Observatory and Lowndesean Professor of Astronomy and Geometry in the University of Cambridge. *Observatory, Cambridge.*
1874. Mar. 16	Berthelot, Professor Marcelin Pierre Eugène. *Boulevard Saint-Michel, 57, Paris.*
1875. Mar. 16	Bertrand, Professor Joseph Louis François. *Paris.*
1869. Mar. 16	Brown-Séquard, Charles Edouard, M.D., F.R.C.P., F.R.S. *Collège de France, Rue Gay Lussac, Paris.*
1869. Mar. 16	Bunsen, Professor Robert Wilhelm Eberard. *Heidelberg.*
1869. Mar. 16	Carus, J. Victor, Professor of Comparative Anatomy. *Leipzig.*
1873. Mar. 15	Cayley, Arthur, LL.D. (Dub.), F.R.S., V-P. R.A.S., &c., Sadlerian Professor of Mathematics in the University of Cambridge. *Cambridge.*

HONORARY MEMBERS—*Continued.*

SECTION OF SCIENCE—Continued.

Date of Election.	
1866. Mar. 16	Clausius, Prof. Rudolf Julius Emmanuel. *Zürich.*
1873. Mar. 15	Dana, James Dwight, LL.D., &c., Professor of Geology and Mineralogy. *Yale College, New Haven, Conn., U. S. America.*
1869. Mar. 16	Daubrée, Prof. Gabriel Auguste. *Ecole des Mines, Paris.*
1876. Mar. 16	Decandolle, Alphonse, Professor of Botany. *Geneva.*
1841. Mar. 16	Dumas, Professor Jean Baptiste, G.C.L.H. *Rue St. Dominique*, 69, *Paris.*
1875. Mar. 16	Gray, Asa, Professor of Botany, Harvard University. *Cambridge, Massachusetts, U. S. America.*
1876. Mar. 16	Haeckel, Ernst, Professor of Zoology. *Jena.*
1880. Mar. 16	Heer, Oswald, Prof. of Botany in Univ. *Zürich.*
1864. Mar. 16	Helmholtz, Professor Hermann Ludwig Ferdinand. *Berlin.*
1873. Mar. 15	Hofmann, August Wilhelm, F.R.S., Professor of Chemistry in the University. *Berlin.*
1879. Mar. 16	Huggins, William, D.C.L., LL.D., F.R.S. *Upper Tulse-hill, London, S.W.*
1874. Mar. 16	§Huxley, Professor Thomas Henry, LL.D., F.R.S. *London.*
1864. Mar. 16	Hyrtl, Professor Karl Joseph. *Vienna.*
1880. Mar. 16	Loomis, Professor Elias. *Yale College, U.S. America.*
1880. Mar. 16	Marsh, Prof. O. C. *Yale College, Conn., U.S. America.*
1882. Mar. 16	Newcomb, Simon. *United States Naval Observatory, Washington.*
1878. Mar. 16	Pasteur, Louis. *Paris.*
1882. Mar. 16	Smith, Henry John Stephen, F.R.S., Savilian Professor of Geometry, Oxford. *Oxford.*
1873. Mar. 15	Stokes, George Gabriel, D.C.L., LL.D. (Dub.), Fellow and Secretary of the Royal Society, F.C.P.S., F.R.S. Ed., &c., Lucasian Professor of Mathematics in the University of Cambridge. *Lensfield Cottage, Cambridge.*
1878. Mar. 16	Thomson, Professor Sir William, LL.D., D.C.L., F.R.S. *Glasgow.*
1882. Mar. 16	Virchow, Rudolph. *Berlin.*
1867. Mar. 16	Würtz, Professor Adolf Karl. *Rue St. Guillaume* 27, *Paris.*

(*One vacancy.*)

SECTION OF POLITE LITERATURE & ANTIQUITIES.

[Limited to 30 Members, of whom one-half at least must be foreigners.]

Elected in the Department of Polite Literature.

Date of Election.	
1869. Mar. 16	Gayangos y Arce, Don Pascual de. *London.*
1869. Mar. 16	Lassen, Professor Christian. *Bonn.*
1849. Nov. 30	Lepsius, Professor Karl Richard. *Berlin.*
1869. Mar. 16	Mommsen, Professor Theodor. *Berlin.*
1863. Mar. 16	Müller, Professor Max. *Oxford.*

Elected in the Department of Antiquities.

1869. Mar. 16	Benavides, Don Antonio. *Madrid.*
1848. Nov. 30	Botta, Paul Emile. *Paris.*
1867. Mar. 16	De Rossi, Commendatore Giovanni Battista. *Rome.*
1841. Mar. 16	Halliwell-Phillipps, James Orchard, F.R.S., F.SS.A. Lond. and Scotland., &c. *Hollingbury Copse, Brighton.*
1854. Mar. 16	Maury, Professor Louis Ferdinand Alfred. *Paris.*
1866. Mar. 16	Nilsson, Professor Sven. *Lund.*
1867. Mar. 16	Visconti, Barone Commendatore P. E. *Rome.*
1867. Mar. 16	Worsaae, Prof. Hans Jakob Asmussen. *Copenhagen.*

Elected since the union of the two classes of Honorary Members in this Section.

1882. Mar. 16	Ascoli, Professor G. I. *Milan.*
1878. Mar. 16	Bradshaw, Henry, M.A., University Librarian, *Cambridge.*
1882. Mar. 16	Bond, Edward Augustus, LL.D., Principal Librarian of the British Museum. *London.*
1882. Mar. 16	Brugsch-Pascha, Heinrich. *Berlin.*
1878. Mar. 16	Curtius, Professor Georg. *Leipzig.*
1875. Mar. 16	Franks, Augustus Wollaston, M.A., F.R.S., F.S.A. 103, *Victoria-street, London, S.W.*
1880. Mar. 16	Fick, Professor F. C. August. *Göttingen.*
1878. Mar. 16	Kern, Professor H. *Leyden.*
1882. Mar. 16	Maine, Sir Henry James Sumner, LL.D., K.C.S.I., Master of Trinity Hall, Cambridge. *Cambridge.*
1878. Mar. 16	Newton, Charles, C.B., D.C.L., F.S.A. *British Museum, London.*
1873. Mar. 15	Nigra, His Excellency Cavaliere Constantino, Italian Minister to Russia. *St. Petersburg.*
1876. Mar. 16	Stokes, Margaret. *Carrig-Breac, Howth, Co. Dublin.*

Date of Election.	
1876. Mar. 16	Stubbs, Rev. William, D.D., Canon of St. Paul's, London, Professor of Modern History, Oxford. *Oxford.*
1873. Mar. 15	Westwood, John Obadiah, Esq., F.S.A., Hope Professor of Zoology, Oxford. *Oxford.*
1875. Mar. 16	Whitney, Prof. William Dwight. *Yale College, Connecticut, U.S., America.*
1876. Mar. 16	Windisch, Professor Ernst. *Leipzig.*

(*One vacancy.*)

SUMMARY.

Life Members	...	...	152
Annual Members	...	...	178
			330
Honorary Members (58 + 5)	...	...	63
		Total, ...	393

Should any errors or omissions be found in this List, which is revised to 1st April, 1882, it is requested that notice thereof may be given to the Secretary of the Academy. He should also be informed of the death of an Member.

As this list will be kept standing in type, it can be readily corrected from time to time.

R. D. Webb and Son, Printers, 74 Abbey-street, Dublin.

MONDAY EVENING, NOVEMBER 13, 1876.

VERY REV. WM. REEVES, D. D., DEAN OF ARMAGH, Vice-President, in the Chair.

Rev. Canon Smith, B.D., and M. F. Cox, Esq., signed the Roll, and were admitted Members.

The Earl of Leitrim, Marriott R. Dalway, Esq., M. P., and Rev. Hill Wilson White, were elected Members of the Academy.

The Secretary read a Paper, by Rev. D. H. Haigh, "On Early British and Irish Inscriptions," Part 1.

The Secretary read a Paper, by Dr. Doberck, "On ζ Coronæ, γ Ophiuchi, γ Coronæ, ξ Boötis, λ Ophiuchi, ξ Libræ, Σ 3121 and other Binary Stars."

[This Paper will be published as Part 15 of Vol. XXVI. of the "Transactions."]

Robert S. Ball, LL.D., read a Paper "On the Precession and Nutation of the Earth and Planets."

[This Paper will be published as Part 13 of Vol. XXVI. of the "Transactions."]

The Secretary read a Paper, by J. Blackwall, F. L. S., and the Rev. O. P. Cambridge, M. A., "On a Collection of the Arachnida of the Seychelles, made by Dr. E. Perceval Wright."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

The Secretary read the following letter:

"20, NORTH GREAT GEORGE'S-STREET,
"DUBLIN, 10*th June*, 1876.

"MY DEAR DR. WRIGHT,

"Seeing in 'Nature' of the 1st inst. a woodcut of a 'Blown-sand Rock,' observed in the expedition of the 'Challenger,' which exhibits stratifications and jointings quite similar to those of rock in the ordinary quarry, I wish to put on record what I have myself done towards the examination of like formations in blown-sand dunes, transported clay, and other adventitious masses.

"The accompanying book, from pages 1 to 9 inclusive, consists of sketches of rock-structure more or less developed, in the sand-hills of Doolin and Liscanor Bays, in the County Clare. These sketches were made in 1868, but I had several years previously noticed the same appearances at Ballybunion, in Limerick, and I had observed a general agreement between these crude formations and the rock-structure of the adjoining districts.

"No. 10 is the only sketch I have preserved of like appearances in transported clay. It is a highly laminated mass, taken from an artificial embankment near Ragatz. But all the adjoining alluvium is of similar structure, due to its deposit by the Rhine, and this lump may have been taken from a mass thrown up from the flat, which would neutralize its evidence. Its structure is horizontal. I regret that I have lost my drawing of a vertically divided face of clay exposed in the mound of an ancient earthen fort at Bull Head, Dingle. I made many other observations of like structural tendencies in hand-transported masses of mud, clay, and quarry *débris* at Vichy, Gastein, and at Buxton; but I lost my notes of these at Truro, two years ago. One of the most striking examples I had noted was a mass of road-stuff on the highway, south of Werfan, on the way to Gastein, which appeared to me to show a remarkable likeness in structure to the highly laminated gneiss rock of the district.

"It is with great diffidence I say anything of glaciers; but noticing no agency of pressure to account for the blown sand or adventitious clay cleavages, I was early led to question the theory which assigns to pressure the rock-like structure noticeable in some ice formations. The sketches from Nos. 11 to 21 inclusive were made with the analogies which those cleavages suggest before my mind, and they may have unconsciously influenced my pencil. But I fancy Professor Forbes, in his 'Alps of Savoy,' had not these considerations to mislead him, when he made his drawings of the very distinct rock structure displayed in the glaciers of the Brenva (p. 203) and Macugnaga (p. 347).

"If my impressions of the existence of a real analogy between the effective causes of those appearances be, to any extent, probable, it may appear desirable to the Academy to possess the original sketches made with a view to investigations which the publication in 'Nature' will soon cause to be taken up by more competent inquirers. I would, therefore,

ask, through you, to solicit the permission of the President for you to read this letter, and present the drawings which accompany it to the Royal Irish Academy, at its next meeting.

"I remain,

"Dear Dr. Wright,

"Very faithfully yours,

"Samuel Ferguson.

"Ed. Perceval Wright, M.D.,
"*Secretary, Royal Irish Academy.*"

A special vote of thanks was given to Dr. Ferguson for his presentation.

The Secretary laid on the table Part 6 of Vol. XXVI. of the "Transactions," being a Report on the Allotropism of Selenium, and on the Influence of Light on the Electrical Conductivity of this Element, by Harry N. Draper, and Richard J. Moss.

Donations to the Library were announced, and thanks voted to the Donors.

Thursday Evening, November 30, 1876.

(St. Andrew's Day.—Stated Meeting.)

Very Rev. Wm. Reeves, D.D., Dean of Armagh, Vice-President, in the Chair.

The Rev. Canon Burke signed the Roll, and was admitted a Member.

The Right Hon. Lord Talbot de Malahide, F.R.S., was elected a Member of Council in the Department of Polite Literature and Antiquities, to supply the place of the Rev. M. H. Close, M.A., resigned.

A Paper, by the Rev. D. H. Haigh, "On Early British and Irish Inscriptions," Part 2, was read.

By permission of the Academy, Mr. F. Ogilby Ross read a Paper, "On the Myology of the Cheetah (*Felis jubata*)."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Monday Evening, December 11, 1876.

Samuel Ferguson, LL.D., Vice-President, in the Chair.

The Secretary of Council read a description, by Miss M. Stokes, Honorary Member of the Academy, of a Series of Photographs of Early Irish Architecture.

It was resolved—"That the thanks of the Academy be given to Miss Stokes for the opportunity she has afforded it of examining the splendid series of Photographs of Early Irish Architecture now exhibited; and for her kindness in accompanying this exhibition with so valuable a description."

Donations to the Library and Museum were announced, and thanks voted to the Donors.

Monday Evening, January 22, 1877.

Very Rev. Wm. Reeves, D.D., Dean of Armagh, Vice-President, in the Chair.

It was resolved—"That a congratulatory address be presented to his Grace the Duke of Marlborough, Lord Lieutenant of Ireland, and that the Officers of the Academy be and are requested to prepare the same."

The Officers, having retired, returned with the following draft of an address, which was adopted:—

"May it please your Grace—

"We, the President and Members of the Royal Irish Academy, beg leave to approach your Grace with our respectful congratulations on your arrival amongst us as the Representative of our Most Gracious Sovereign.

"The learned body to which we have the honour to belong was constituted by Charter in the year 1785, for the purpose of promoting the study of Science, Polite Literature, and Antiquities. Since that time it has laboured, not without success, in this high vocation, and has won an honourable place amongst kindred Societies at home and abroad.

"It has provided a field and supplied a stimulus for the development and exercise of Irish genius. It has made important contributions to knowledge in various branches of scientific inquiry; it has brought together in its Museum and Manuscript Collection abundant and trustworthy materials for the illustration of our National Antiquities, and of the language, literature, and social life of the Hiberno-Celtic race.

"Your Grace is, by virtue of your exalted office, Visitor of the Academy. We trust you will find reason to look on its labours with the same favour with which they were regarded by your distinguished predecessors in the government of Ireland; and we are sure we may rely on your Grace's countenance and support in our endeavours to guard its interests, maintain its character, and extend its usefulness."

It was Resolved—"That the Officers of the Academy take the proper steps to have the same presented to his Grace."

Samuel Ferguson, LL.D., V.P., read a Paper "On some Sculptures on the Great Cross at Clonmacnoise."

By permission of the Academy, Chichester Bell, M.D., read a Paper "On a Series of Bases derived from Pyrrol, and some Compounds allied to them and to Mussic Acid."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Part 1.]

By permission of the Academy, Dr. E. L. Moss, R.N., read a Paper "On the Glaciation by Sea Ice."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Professor J. E. Reynolds read the second of a series of Reports from the Chemical Laboratory of Trinity College, Dublin. No. 2. "On Mr. Early's Method of Analysing Ferroso-ferric Silicate."

[This Report will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1. For No. 1, *vide* "Proceedings," Second Series, Vol. II., p. 731.]

The Secretary laid on the table the "Proceedings" of the Academy, Second Series, Vol. II., Science, Part 7, January, 1877. This number concludes Volume II.

Donations to the Museum and Library were announced, and thanks voted to the Donors.

Monday Evening, February 12, 1877.

Samuel Ferguson, LL.D., Vice-President, in the Chair.

The Secretary reported that His Excellency the Lord Lieutenant had received the President and Members of the Academy at the Castle, on the 22nd of January, and that his Grace had been pleased to return the following Answer to the Address of the Academy, which had been duly presented to him :—

"Mr. President and Members of the Royal Irish Academy—

"I thank you for the Address you have read to me. Your congratulations on the high appointment which the Queen has conferred on me I greatly value.

"It is most gratifying to me, on my arrival in Ireland, to be welcomed by a body so important and cultivated as the Royal Irish Academy ; one which, incorporated by Royal Charter nearly a hundred years ago, for the purpose of stimulating the study of literature and the pursuit of scientific research, still continues in its enlightened course, and carries out in such an admirable and successful manner the original intentions of its founders. The Museum, with its ancient manuscripts, will be a matter of special interest to me, and it will afford me much pleasure to be able on some future occasion to inspect the valuable collection which it contains.

"To be the Visitor of such an Institution as yours, gentlemen, ranking high as it does among all kindred Societies, is to me a source of pride, and I shall consider it the privilege of my position to assist you as far as possible in extending its usefulness, in guarding its interests, and in maintaining the great celebrity which it has obtained."

It was resolved that the Answer of His Excellency to the Address presented by the Academy should be entered on the Minutes.

The Secretary read a Paper, by C. E. Burton, B. A., entitled, "Notes on some Drawings of the Planet Mars."

[These will be published as Part 12 of Vol. XXVI. of the "Transactions."]

Henry Hennessy, F. R. S., read a Report (Part 1), "On Experiments to determine the Influence of the Molecular Condition of Fluids on their motion when in Rotation, and in contact with Solids."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

The Secretary, Dr. E. P. Wright, read a Paper "On a Parasitic Green Alga, forming a new species of Cohn's genus Chlorochytrium;" also a Paper "On Chytridia Parasitic on Ectocarpi."

[These Papers will be published as Parts 9 and 10 of Vol. XXVI. of the "Transactions."]

Donations to the Library were announced, and thanks voted to the Donors.

Monday Evening, February 26, 1877.

Samuel Ferguson, LL.D., Vice-President, in the Chair.

The Secretary read a Paper, by Angus Smith, M.D., "On the Revival of Manuscripts on Parchment."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

The Secretary read a Paper, by Robert S. Ball, LL.D., "On a Method of Regulating a Clock intended to show Mean Time."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

The Secretary read a Paper, by J. E. L. Dreyer, M. A., as "A Supplement to Sir John Herschel's General Catalogue of Nebulæ and Clusters of Stars."

[This Paper will be published as Part 11 of Vol. XXVI. of the "Transactions."]

Donations to the Library and Museum were announced, and thanks voted to the Donors.

The Academy was then, by special resolution, adjourned to Monday next, March 5th, 1877.

MONDAY EVENING, MARCH 5, 1877.

(Special Meeting.)

SAMUEL FERGUSON, LL.D., Vice-President, in the Chair.

The Secretary of Council announced that the President of the Academy had intimated that he would not present himself for re-election at the approaching Stated Meeting.

The Secretary of Council read the following Report of the Council, as to negotiations with the Government, and the letters from the Government communicating the conditions proposed as to the transfer of the Museum of the Academy to the new "Science and Art Museum," and as regards the re-transfer of the Vote for the Academy to the charge of the Irish Government, as well as to the future provision for the maintenance and augmentation of the collection of Antiquities.

REPORT OF THE COUNCIL.

ON the last occasion (26th of June, 1876), when the Academy had under its consideration a Report from the Council in relation to the question pending with the Government as to the transfer of the charge of its Vote from the Chief Secretary for Ireland to the Science and Art Department, a Petition to the House of Commons on the subject was adopted, and the Council were authorized to take the requisite steps for its presentation, if they should find it advisable. Further time having elapsed without any communication having been received from the Government, and the close of the Session being at hand, your Petition was entrusted for presentation to the Members for the City of Dublin, and just before the rising of Parliament was presented by Mr. Maurice Brooks, and was one of those selected by the Committee on Public Petitions to be printed in their last Report for the Sessions (31st Report, Appendix, p. 228).

The Council were gratified to observe that the attention of the House of Lords was called to the subject by Lord O'Hagan, who moved for a Return of "copies of all public official correspondence (commencing 8th of February, 1876) between the Irish Government, the Treasury, the Science and Art Department, the Royal Dublin Society, and the Royal Irish Academy, on the subject of the proposed Establishment of a Science and Art Department in Dublin."

This motion was acceded to on the part of the Government by the Duke of Richmond and Gordon, Lord President of the Privy Council.

About the same time your Council received from their Excellencies the Lords Justices of Ireland (in the absence of His Grace the Duke of Abercorn) an intimation of their willingness to receive a Deputation on the subject of the transfer of the Academy's Vote. They accordingly waited on their Excellencies (the Lord Chancellor and the Vice-Chancellor) at Dublin Castle, on the 27th June, 1876, and presented the following Memorial, the importance of which seems to the Council to justify their now placing it before the Academy:—

"May it please your Excellencies,

"We, the Council of the Royal Irish Academy, beg to approach your Excellencies in the hope of inducing you to exercise the influence of your high office to obtain a reversal of the action of certain Departments of the Government, by which the charge of the Parliamentary Vote for the Academy has been transferred from the Irish Government to the Science and Art Department, South Kensington.

"It is probably within the knowledge of your Excellencies that a communication was, in February last, addressed to the Academy by the Right Hon. Viscount Sandon, Vice-President of the Committee on Education of Her Majesty's Privy Council, propounding a scheme which involved a proposal for the transfer of the Academy's Collection of Antiquities to a Science and Art Museum in Dublin, to be provided by the State, under an officer of the Establishment known as the Science and Art Department, who would be the medium of communication with that Department.

"The Academy, whilst consenting to the proposed transfer, attached thereto certain conditions, and, amongst others, the following:—That the Academy should not be subject, in the conduct of its affairs, or the expenditure of its grants, to any control on the part of the Science and Art Department, or any of its officers; and should continue to be accountable, as at present, through Her Majesty's Irish Government, for all sums voted by Parliament.

"To the letter embodying these conditions we have never received any reply, further than a formal acknow-

ledgment of its receipt, though we have been anxiously expecting one during the period of more than three months which has since elapsed. But, on the 17th of May, we were informed by the letter of the Under Secretary, to which we have already referred, that the charge of our Vote had been transferred to the Science and Art Department.

"It may be supposed by some that the Academy, by its action in relation to Lord Sandon's proposal, has set itself in opposition to the establishment of a Science and Art Museum in Dublin, and is thus impeding the bestowal of a great benefit on the people of Ireland. No representation could be more unfounded. What was sought from us in his Lordship's letter was the union of our Antiquarian Collections to the proposed new Museum. To this we distinctly assented, on conditions such as we thought were required in the interest of the country, involving arrangements similar to those which were accorded in a like case to the Scottish Society of Antiquaries, and under which the National Collection of Antiquities in England is managed by the Trustees of the British Museum, without interference from the Science and Art Department, which has no concern with Archæology.

"The only reasons given for the transfer of the charge of our Vote are founded in misapprehension. It is stated that such a change was recommended by the Commissioners of 1868. But this is an erroneous statement, not supported by the Report of the Commissioners, and contradicted by some of them, who have come forward to repel the assertion.

"The other reason alleged is, that the change has been introduced to further a proposed amalgamation of 'Scientific Institutions in Dublin.' But the Government has not given its sanction to any such amalgamation, and it was not proposed in Lord Sandon's letter. The project of such an amalgamation has been rejected by the Academy, and the idea of forcing it on a reluctant body may be treated as quite out of the question.

The Royal Irish Academy is not an Educational Institution like those with which the functions of the Science and Art Department properly connect it, but a learned Society, occu-

pying in this country a position analogous to that of the Royal Society in England, and, in Scotland, of the Royal Society of Edinburgh. We feel bound to maintain it on the same level of dignity with those bodies, and not to accept for it a subordination which, we doubt not, they would repudiate as unbecoming their position. Those distinguished Societies have not been placed under the financial or other control of the Science and Art Department; and when the step has been taken in relation to them, it will be time enough, we submit, to propose it to us.

"That a control exercised by the Department over the Academy in monetary matters would extend to the scientific and literary sphere, we have no doubt; and we believe the Department to be entirely unfitted to exercise any such authority over the proceedings of a body like the Academy.

"The Irish Government is the natural guardian of the rights of the body which is the chief representative of Science and learned research in Ireland. It is likely to be better informed than any other on our position, our deserts, and our requirements. Our connexion with it has worked in a perfectly satisfactory manner. That this connexion should be terminated, and the charge of our grant transferred to a Body in London, appears to us an unnecessary disturbance of relations which were not complained of. To quote words used by the Academy in 1862, when deprecating a similar attempt, such an innovation would 'compromise the honour and interests of an important National Institution, for an alleged official convenience of the most inconsiderable kind.'

"We find it difficult to believe that the distinguished nobleman who now presides over the Irish Government could have consented to the transfer of the charge of the Academy's vote, if His Grace had been aware of the unreality of the reasons assigned for the change. And we are confirmed in this opinion by the fact that His Grace has lately marked his confidence in the Academy by requesting, without any application from us to that effect, that we would undertake the editing of certain Irish Annals, the publication of which was considered by His Grace important, but has been suspended by the untoward action now complained of.

"It is not agreeable to this Academy, nor, we make bold to add, to this Nation, that the functions of superintendence and control of Irish affairs still left in the hands of Her Majesty's Irish Government should be one by one taken from it, and transferred to English authorities. And the question will inevitably be raised by the present transaction, whether Her Majesty's Government did not, in 1868, exercise a wise judgment in deciding 'to constitute a separate Department of Science and Art for Ireland,' which, as stated by Mr. Ward Hunt, then Chancellor of the Exchequer, should be 'a sister to, and not subordinate to, the English establishment.'

"It is not alleged that there is anything in our present state or recent proceedings to supply a motive for interference with us. Never has the work of the Academy been carried on with greater energy or industry than at present. All its Departments are in a state of healthy activity. In addition to its former operations, by the aid of the increased grants which it has of late enjoyed, it has stimulated and aided original scientific research, and is multiplying, for the benefit of scholars at home and abroad, copies of the most valuable Celtic Manuscripts. It cannot be alleged that there is any misuse or want of circumspection in applying the funds placed at its disposal by the bounty of Parliament. Why, then, should a change be made in its position, offensive to its Members, and dangerous to its public usefulness?

"The Academy depends, for its reputation among the learned Societies of the world, and for its beneficial influence at home, without which it had better cease to exist, on the voluntary researches and unpaid personal services of its Members. Such helps to learning do not flourish except under the conditions of conscious independence, and a continuing sense of security; and we are convinced that the change against which we protest would, if carried out, be, in a great degree, destructive of the higher motives to scientific and literary exertion in this part of Her Majesty's dominions.

"Signed on behalf of the Council,

"W. Stokes, *President.*"

Their Excellencies received the Deputation very graciously, and conveyed to those present the impression that the views submitted were looked upon favourably by their Excellencies.

About this stage of the negotiations a sum of £500, portion of the £2000 voted to the Academy by Parliament (in addition to £500 already received through the usual channel) was placed, unasked for, to the credit of the Academy by the Paymaster-General, and subsequently we received an intimation that it had been issued by the Science and Art Department.

No reply to our communications, however, was received for some months, and the Council became apprehensive that it would be necessary for them, in order to meet the urgent requirements of the Academy, to have recourse to its funded capital, under the authority received from the Academy, authorizing them, if necessary, to sell a portion of its invested property. Before, however, taking so serious a step, it was thought advisable to apply to the Bank of Ireland for permission to overdraw to the extent of £500. The Council think it right to acknowledge the prompt and liberal manner in which this request was granted by the Governor of the Bank.

An intimation having been received from the Chief Secretary, that he desired a conference on the subject at issue between the Government and the Academy, the Secretary of Council had interviews with him, which resulted in the adoption by the Council, on the 4th of December, 1876, of the following Resolution :—

"That the Council is prepared to re-open negotiations for the transfer of its Museum to the new establishment in Dublin, contemplated by the Government, on the following basis, viz. :—That after such transfer, if it should be agreed upon, the part of the Academy's grant given for the care and maintenance of the Museum shall be accounted for by the Department of Science and Art, the Academy retaining the same amount of control over the management of its collection as is enjoyed in a similar case by the Scottish Society of Antiquaries, and due provision being made for its preservation in its integrity as a National collection in Dublin, whilst the rest of the Academy's grant shall remain on its present footing, and shall continue to be accounted for as heretofore by the Chief Secretary for Ireland."

On the appearance of the Civil Service Estimates for 1877-8, early

last month, it was found that the Academy's Parliamentary Grant no longer appeared amongst the Irish votes, but under those to be accounted for by the Science and Art Department.

It was, therefore, all the more gratifying to the Council to receive immediately afterwards the Letters which it now hastens to communicate to the Academy. They are, for convenience, arranged in chronological order.

[1.]

"Science and Art Department,

"South Kensington, S.W.,

"*8th February*, 1877.

"Sir,

"The Lords of the Committee of Council on Education have given their careful consideration to Sir Michael Hicks Beach's letter, dated 7th November, 1876, to the Secretary of the Treasury, on the subject of the re-transfer of the vote for the Royal Irish Academy to the Irish Government, which was forwarded by Mr. Law to this Department on the 16th November.

"I am to request that you will inform the Lords Commissioners of Her Majesty's Treasury, that the Lords of the Committee of Council on Education are glad to find that the general scope of the proposals of the Royal Irish Academy, as they anticipated would be the case, is not inconsistent with their views as expressed in my letter of the 8th February, 1876.

"It is hardly necessary to remind their Lordships that the scheme proposed in that letter was always considered to be open to such modifications in details as might appear to be desirable, after the Government had had the advantage of hearing the criticisms upon it of those gentlemen in Ireland who, from their knowledge and experience, have a just influence in such matters, provided always that the modifications did not interfere with the ultimate success of the great object which Her Majesty's Government had in view, namely, the establishment in Dublin of a comprehensive National Museum of Science and Art, which has been generally desired for many years.

"My Lords are, therefore, prepared to accede to the suggestion of the Royal Irish Academy, that the same course should be taken respecting the collection of the Academy as that which was adopted by the Treasury with regard to that of the Society of Antiquaries of Scotland. Their Lordships might not unreasonably have demurred to placing the Royal Irish Academy in a similar position to the Society of Antiquaries of Scotland, inasmuch as the collections of the latter were all acquired by private funds, whereas a large proportion of those of the Royal Irish Academy have been purchased out of funds provided by Parliament; but My Lords are willing to waive these considerations, so as to consult, as far as possible, the wishes of the Royal Irish Academy, and they propose to follow closely the precedent of the Treasury minute of 1851, respecting the Scotch Society, only introducing such modifications as are absolutely required by the different circumstances of the two cases.

"My Lords, therefore, desire to call the attention of the Lords Commissioners of the Treasury to the appended copy of a minute (in which the necessary alterations are shown in red ink) as embodying the conditions under which the Lords of the Committee of Council on Education are of opinion that the proposals of the Royal Irish Academy should be accepted.

"On receipt of a resolution of the Academy accepting the conditions appended, and undertaking to transfer their collections to the new Science and Art Museum, as soon as the building is ready to receive them, My Lords will be prepared to recommend to the Lords Commissioners of Her Majesty's Treasury that the votes now taken for the Royal Irish Academy shall be re-transferred to the Irish Government, it being understood that the votes now taken for Museum purposes by the Royal Irish Academy shall cease as soon as the Science and Art Museum is ready to receive their collections.

"I have, &c.,

"(Signed), Sandon.

"The Secretary
"To the Treasury."

"Conditions.

"1. The entire collection of antiquities, coins, and medals, be-

longing to the Royal Irish Academy, with such additions as may be hereafter made to them, and the cabinets, glass cases, &c., in which they are contained, to be conveyed to the Lords of the Committee of Council on Education, to be retained in Ireland on behalf of the public.

"2. Fit and proper accommodation to be at all times provided in a public building for the preservation and exhibition to the public of the collection of antiquities, and for the meetings of the Royal Irish Academy; but no stipulation can be entered into permanently to appropriate particular apartments in the new Museum building to these objects.

"3. The charge and custody of the collection of antiquities to be entrusted to the Royal Irish Academy, subject to such regulations and special directions as may from time to time be prescribed by the Lords of the Committee of Council on Education.

"4. The funds required to alter and adapt the apartments in the Science and Art Museum for the reception of the collection, to furnish the requisite means for the preservation and exhibition of the Museum, and to pay the salaries of additional servants, to be provided by the Lords of the Committee of Council on Education, by an estimate to be submitted to Parliament.

"My Lords are of opinion that it would not be conducive to the object which all parties have in view, in making this arrangement, that express stipulations should be entered into with the Royal Irish Academy on detailed points of management; but the Members of that Society may rest assured that it will be the desire of the Lords of the Committee of Council on Education so to exercise the general control which they must retain over all collections exhibited at the public expense as to leave the Royal Irish Academy as unfettered in the charge and management of the Museum as circumstances will allow."

[The alterations shown in red ink in the original are underlined above.]

[2.]

"Treasury Chambers,

"17*th February*, 1877.

"Sir,

"I am directed by the Lords Commissioners of Her Majesty's Treasury to transmit to you herewith copy of a letter of the 8th inst. from the Science and Art Department, and of the enclosure therein, on the subject of the re-transfer to your Department of the vote for the Royal Irish Academy; and I am to state, that if the proposal now made meets with the approval of His Grace the Lord Lieutenant, My Lords should not feel called upon to make any objection to it.

"I am, Sir,

"Your obedient Servant,

"The Right Hon. "W. H. Smith.

"Sir M. Hicks Beach, Bart., M. P."

[3.]

"Dublin Castle,

"26*th February*, 1877.

"Sir,

"Adverting to former correspondence relative to the transfer of the antiquarian collections commonly known as the Museum of the Royal Irish Academy, to the National Science and Art Museum, which it is proposed to establish in Dublin; and also to the transfer of the charge of the vote for the Royal Irish Academy to the Science and Art Department, I am directed by the Lord Lieutenant to acquaint you, for the information of the Royal Irish Academy, that His Grace has been in communication with the Lords Commissioners of Her Majesty's Treasury and the Science and Art Department on the subject, with the view of devising such modifications in detail of the original scheme proposed in Lord Sandon's communication of the 9th February, 1876, directed to the President of the Academy, as, while not interfering with the establishment in Dublin of a comprehensive National Museum of Science and Art, would at the same time meet the objections entertained by the Members of the Royal Irish Academy to the original scheme, and also to the transfer of the

charge of their vote from the Lord Lieutenant to the Science and Art Department.

"His Grace desires me to transmit herewith a copy of a letter dated 17th instant, received from the Treasury, together with a copy of a letter enclosed therein from the Science and Art Department, and in which a modified scheme is proposed.

"His Grace feels assured that the Academy will receive this proposal in the same friendly spirit in which it is made, and he confidently trusts that it will meet with their approval.

"I am, Sir,

"Your obedient Servant,

"T. H. Burke.

"The Secretary,

"Royal Irish Academy."

It is to be observed that whilst the Government has, on the one hand, stipulated for certain conditions, which, *mutatis mutandis*, are identical with those to which the Society of Antiquaries of Scotland readily assented, on the other hand, in deciding "that the proposals of the Academy should be accepted," Government has conceded the conditions sought by the Academy, not only as regards the re-transfer of its vote to the charge of the Irish Government, but also as to the future provision for the maintenance and augmentation of the Museum, and its preservation in Dublin as a Museum of our National Antiquities, distinct from other collections, and under the care and management of the Academy.

The Council, being of opinion that the Government has virtually agreed to all that was sought for by the Academy, either in its own interest or for the benefit of the Irish public, have no hesitation in advising the Academy cordially to accept the terms proposed by the Government, and they recommend the Academy to authorize the Council to take all steps necessary to bring the negotiations to a close.

The Secretary of the Council moved the adoption of the Report.

It was moved, as an amendment, by George Sigerson, M.D., and seconded by James John Kelly, Esq.:—

"That it be referred back to Council to report that, as to paragraph 3, they do not recommend the Academy to accept that condition, unless the words, 'unless the Academy object to any particular rule or regulation,' be added thereto."

The proposer and seconder of the foregoing amendment, by permission of the Academy, having withdrawn it, the Report was adopted.

It was moved by J. Kells Ingram, LL.D., seconded by Sir Robert Kane, F.R.S., and Resolved unanimously—

"That the Academy, accepting the conditions set forth in the letter of Lord Sandon (of February 8, 1876), recently transmitted by the Irish Government, undertakes to transfer its Museum to the proposed National Museum of Science and Art in Dublin, as soon as the building may be ready to receive it; and desires at the same time to express its sense of the considerate manner in which Her Majesty's Government have met the views of the Academy."

The Academy then adjourned.

Friday Evening, March 16, 1877.

(Stated Meeting.)

Samuel Ferguson, LL.D., Vice-President, in the Chair.

On the proposition of the Chairman,

It was Resolved—

"That Bye-law 4 of Chapter IX. be for the present suspended."—

Visitors were then admitted.

The Secretary of the Council read the following letter from the President:—

"5, Merrion-square, North, Dublin,
"*March*, 14*th* 1877.

"My dear Dr. Ingram,

"I am compelled by the state of my health to ask you to announce at the Stated Meeting that it is my desire to retire from the office of President of the Academy, which I have always held to have been the greatest honour of my public life.

"I beg you will convey to all the Members of the Academy my feelings of gratitude, and my earnest thanks for the distinction they have conferred upon me, and the kindness they have invariably shown me while I filled the office.

"Faithfully and gratefully yours,

(Signed) "William Stokes."

It was moved by Lord Talbot de Malahide, and seconded by Dr. Lyons, and

Resolved unanimously :—

"That the Academy receives with much regret the announcement of the retirement of Dr. Stokes from the office of President; and that the Secretary be requested to convey to him the grateful thanks of the Academy for the eminent services rendered by him in its behalf, and for his dignified and zealous discharge of his functions as President of the Academy."

It was proposed by James Apjohn, M. D., F. R. S., and seconded by Alexander G. Richey, LL.D :—

"That Sir Robert Kane, F. R. S., &c., be elected President of the Academy."

It was proposed by Rev. J. H. Jellett, B. D., and seconded by Lord Talbot de Malahide, F. R. S. :—

"That the Rev. Samuel Haughton, F. R. S., &c., be elected President of the Academy."

The Ballots for President and Members of Council, and Officers, and for an Honorary Member, being opened, the Chairman appointed Rev. Dr. Carson and Dr. M'Sweeny Scrutineers for the election of President, Council, and Officers; and Mr. Porte and Mr. G. C. Garnett Scrutineers for the election of Honorary Member.

The Secretary of Council brought up the following Report of the Council for the year 1876–77 :—

Report of the Council for the Year 1876–7.

Since the date of the last Report of the Council, the following Parts of the Transactions have been published :—

In the department of Science :—

Vol. XXVI.—Part 4. On ω Leonis, considered as a Revolving Double Star; by W. Doberck, Ph. D.

Vol. XXVI.—Part 5. Report on the Exploration of Shandon Cave; by Professor A. Leith Adams, F. R. S.

Vol. XXVI.—Part 6. Report on the Allotropism of Selenium, and on the Influence of Light on the Electrical Conductivity of this Element; by Harry N. Draper, F. C. S., and R. J. Moss, F. C. S.

And the following is in the press :—

Vol. XXVI.—Part 7. Catalogue of, and Observations on, the Red Stars; by John Birmingham.

In the department of Polite Literature and Antiquities :—

Vol. XXVII.—Part 1. On the Bell of St. Patrick; by the Very Rev. William Reeves, D. D., is in type and will be laid on the table at this Meeting.

Dr. Whitley Stokes' Edition of the Felire of Oengus is still in progress. The entire triple text and translation have been printed, and the Glossary is now being proceeded with. To accelerate the completion of the work, the Council have authorized the Editor, at his request, to have the Glossary printed at Calcutta, care being taken to make it harmonize in style with the rest of the volume.

Dr. William K. Sullivan's Edition of the Tain-bo-Cuailnge is also still in the printer's hands.

Of the Science portion of the New Series of our Proceedings, there have been published within the year, Part 6 of Vol. II., in July, 1876, and Part 7, in January of the present year (1877.) These Parts contained all the Science Papers (with three exceptions) laid before the Academy in the Session of 1875–6. Part 12 of Vol. I. (Second Series), containing papers on Polite Literature and Antiquities, will very soon be ready for issue.

Within the past year, papers by the following authors were read before the Academy :—

In the department of Science :—by Professor R. S. Ball; Mr.

G. H. Kinahan; Dr. Doberck; Professor J. Emerson Reynolds; Dr. David Moore; Mr. E. T. Hardman; Professor E. Perceval Wright; Mr. A. G. More; Professor Edmund Davy; Rev. J. H. Jellett; Mr. Harry N. Draper and Mr. Moss; Mr. George Porte; Professor J. R. Young; Dr. Moss; Mr. John Birmingham; Dr. Samuel Ferguson; Mr. A. M'Alpine; Professor M'Nab; Mr. J. Blackwall and Rev. O. P. Cambridge; Mr. F. Ogilby Ross; Dr. Chichester Bell; Mr. H. B. Brady; Mr. C. E. Burton; Professor Henry Hennessy; Mr. J. E. L. Dreyer, and Dr. Angus Smith.

In the department of Polite Literature and Antiquities:—by Mr. W. F. Wakeman; Dr. Samuel Ferguson; and Rev. D. H. Haigh.

Miss Stokes, Honorary Member of the Academy, exhibited at one of our Meetings a splendid series of photographs, illustrative of Early Irish Architecture, and accompanied the exhibition with a communication containing a description of the structures thus represented, and also a general view of the History of our Architecture down to the Anglo-Norman invasion.

The Librarian has found it necessary to undertake an entire rearrangement of the Library. All books relating to Ireland have been brought together into the recesses of the gallery facing the entrance. Books on archæological matters (in the widest sense) are being gradually transferred to the Reading-room, in which, when all are collected, it is intended to arrange them on a system of classification which will enable readers to discover at once the literature of each subject and of its particular branches, so far as it is contained in the Library. The foreign reviews and other periodicals have been collected from all parts of the Library, and placed in the recesses on the north side of the room, where they are arranged according to the countries in which they are published.

In the department of manuscripts, we have to report, with respect to the Edition of the Book of Leinster, which we have undertaken with the assistance of the Board of Trinity College, that the transcription has been continued as far as page 300, and that 280 pages have been already printed off. It is expected that the whole of the work will be completed in the summer of 1879.

Dr. Atkinson, by appointment of the Academy, appeared as its Delegate at the International Congress of Orientalists, which met at St. Petersburg in September, 1876.

Since the date of our last Report, various objects of interest have been added to the Academy's Museum. Amongst these may be specially mentioned portions of a beautifully carved Harp, bearing inscriptions in Irish, and the date, 1621, known as the "Dalway Harp;" a set of silver-mounted ivory Bag-pipes of the middle of the last century; and an ancient Boat, recently found in the County of Galway—the last being a donation from the Rev. Sir William Ross Mahon, Bart.

The valuable collection of Irish antiquities belonging to the late Mr. Walsh of Dromore has also been purchased, comprising objects in gold, silver, and amber; weapons and other articles of bronze, flint, and stone; wooden utensils, earthen cinerary urns, &c. All these have been temporarily deposited in wall-cases, on the south side of the Reading-room gallery. The arrangement of the Museum in the first floor and basement continues to advance with systematic regularity. Its condition is now eminently satisfactory.

The decorative painting of the walls and ceilings of the Long Room has just been completed by the Board of Works, and a considerable improvement thus effected in the general appearance of this part of the Museum.

The Hand-book for Visitors to the Museum, intended for popular use, which was announced in our last Report as in preparation, has since been published, and will, we trust, contribute to a more general understanding and appreciation of our antiquarian collections—especially by such of the working classes as may avail themselves of the evening opening.

It will be remembered that in April, 1875, the Council offered Two Premiums of Fifty Pounds each for the best Reports or Essays on the present state of the Irish Language and Literature in the Provinces of Ulster and Leinster. Three Essays were sent in to compete for these Premiums. The Council were not of opinion that any of these Essays was of a nature to deserve the full award of a Premium. But the knowledge and industry displayed by one of the writers, Mr. Francis Keane, seemed to entitle him to a substantial mark of consideration, and they accordingly presented to him a sum of Twenty Pounds as an honorary donation.

The most important part of the work of the Council during the past year consisted of the negotiations and other proceedings ren-

dered necessary by the unsettled state of the relations between the Government and the Academy. A detailed account of these has already been laid before the Members, and they are therefore not dealt with in the present Report. From the resolution of the Academy not to acquiesce in the transfer of the charge of its vote from the Irish Government to the Science and Art Department, it resulted that a large portion of the Parliamentary Vote did not reach us in time to be applied to the objects to which it would, in the ordinary course, have been devoted. We were thus obliged to defer proceeding with the printing of the "Annals of Ulster," though the publication of that work had been undertaken by us at the instance of the late Lord Lieutenant of Ireland. To the same cause it is due that we were not able until near the end of the past year to distribute the fund annually placed at our disposal by Parliament for aiding Scientific Research by providing suitable instruments and materials. While constrained to exercise a cautious reserve with respect to these items of our expenditure, we endeavoured, as far as possible, to prevent what we regard as the most important part of the Academy's work—namely, the printing of Papers read before us—from being seriously obstructed by the temporary failure of our supplies. Now that a satisfactory solution has been arrived at of the questions so long at issue between the Academy and the Government, the Papers read since November last will speedily be published, and it may be confidently expected that every branch of our operations will proceed with renewed energy and efficiency.

The grants in aid of the preparation of Scientific Reports, recommended by the Committee of Science, approved by the Council, and now submitted for the sanction of the Academy, are as follows:—

£50 to Rev. Professor Haughton, M. D., for Reports on the Tidal Constants of the Irish Coast; being the second instalment of the sum of £100 required for the expenses of calculations.

£10 to Dr. C. Bell for further Experiments on Pyrrol.

£50 to Dr. R. S. Ball towards the expenses to be incurred in the reduction of the recorded Observations of Jupiter's Satellites, preparatory to a re-discussion of their Theory.

£25 to Dr. Reynolds and Rev. Professor Haughton, M. D., for Experiments on the Dynamical Coefficients of Friction, at low velocities, between fluids and solids.

£25 to Rev. J. H. Jellett, B. D., for Experiments on the action of a Galvanic current on a beam of polarized light.

£40 to Dr. E. P. Wright, towards defraying the expenses of obtaining a series of drawings of some of the lower Algæ—the drawings to be the property of the Academy.

The Council have addressed to the Commissioners of Church Temporalities a request that they will, so far as they are empowered by the Irish Church Act of 1869, cause all the Ecclesiastical Round Towers to be treated as National Monuments; and, further, that they will take steps to have the buildings at Clonmacnoise, including the Tower, placed in charge of the Board of Works, and revested, so as to come within the operation of the Act. We have reason to believe that this representation will be attended with satisfactory results.

Fourteen Ordinary Members have been elected since the 16th of March, 1876, viz. :—

1. Michael F. Coxe, M. D.
2. Francis E. Clarke, M. D.
3. Rev. John Grainger, D. D.
4. Rev. William McIlwaine, D. D.
5. Walter Meyers.
6. G. Gerald Tyrrell.
7. William H. Byrne.
8. William Gillespie.
9. James Edward Kelly, M. D.
10. Rev. Richard Travers Smith, B. D.
11. Harry N. Draper.
12. The Earl of Leitrim.
13. Marriott R. Dalway, M. P.
14. Rev. Hill Wilson White.

We have lost by death within the year one Honorary Member—

The Abbé Jean Benoit Désiré Cochet, elected in 1863;

and nine Ordinary Members, viz. :—

1. Rev. J. Bewglas, elected January 8, 1849.
2. Edward Bewley, elected December 11, 1843.
3. Adolphus Cooke, elected June 9, 1845.
4. Sir John Esmonde, Bart., elected January 10, 1870.

5. The Ven. F. Goold, elected June 14, 1858.
6. J. H. Pickford, elected December 11, 1843.
7. Colonel Meadows Taylor, elected January 12, 1863.
8. Sir William R. Wilde, elected June 10, 1839.
9. Robert Wilson, elected June 10, 1849.

One of these names, that of Sir William Wilde, will always be honourably associated with the work of the Royal Irish Academy; and a few words must here be said of the great services he rendered to Irish Archæology, and the labours which entitled him in an eminent degree to our grateful remembrance. From his early years a devoted student of the history and antiquities of our country, he became in after-life an earnest disciple of the school which, discarding the fanciful doctrines and vicious modes of inquiry which had so long disfigured and discredited Irish archæological study, proposed to itself to subject researches of this kind to the rigorous discipline of scientific method. Placing before himself the idea that in our Museum were to be found some of the most precious materials for the social palæontology of our country—for the study of its primitive races, their ideas, manners and mode of life—he applied himself to the classification and cataloguing of its contents, with the double view of assisting the systematic inquirer and enlightening the general mind of our people on these subjects. Not only did he prepare himself for this task by a lengthened and minute study of the collection itself, but, while the work was in progress, he visited the principal Museums of Northern Europe, in order to acquaint himself by personal inspection with the analogies and relations which connect Irish pre-historic remains with those of Scandinavia. This indicates an important feature in the spirit which characterized his researches, namely, the habitual application, in this field of inquiry, of the comparative method which is now universally acknowledged to be one of the most effective instruments in the study of archæology and the early history of mankind. He completed the Catalogue of the gold, copper and bronze articles in our Museum, and of the objects composed of stone, earthen, vegetable, or animal materials; and these portions of the work have since been the constant companions and guides of all who have wished to derive profit from an examination of our antiquarian treasures.

In the transfer of our collection to a new place in our premises,

rendered necessary by the growing requirements of the Museum, the order of his arrangements has been scrupulously preserved; and, by a system of key-reference adopted in the re-deposit, the connexion of each article with its description in the Catalogue has been maintained unbroken.

The labours of Sir William Wilde were not restricted to the field of antiquarian study. His "Narrative of a Voyage to Madeira," his work on Austria, his "Popular Superstitions of Ireland," his "Closing Years of Dean Swift's Life," and his works on Irish Topography—so abounding in local and traditional knowledge, and so marked by genial appreciation both of the national character and of the beauties of the scenes described—all these are literary works of distinguished merit; whilst his professional writings, of which his Treatises on Aural Surgery may be specially mentioned, and his Reports contributed to the volumes of the Irish Census, give him an honourable place in the domain of Science.

Of his practical exertions for the benefit of his profession, or the good of his fellow-countrymen generally, this is not the fitting occasion to speak; nor of the kindly spirit and attractive social qualities which won for him a large circle of admiring friends.

Various honorary titles and decorations were conferred upon him in recognition of his public services. He received a Diploma from the University of Upsala, and was elected an Honorary Member of the Society of Antiquaries of Berlin. He was also presented with a decoration of the Order of the Polar Star, thus becoming a Chevalier of the Kingdom of Sweden. He received the honour of Knighthood in acknowledgment of his services to Statistical Science in connexion with the Irish Census. The Board of Trinity College conferred on him the Degree of M. D., *honoris causâ*. And this Academy, by presenting to him the Cunningham Medal, the highest special mark of distinction in its power to bestow, expressed its grateful sense of the service rendered to Scientific Archæology in general, and to our body in particular, by his Catalogue of the Museum.

A brief tribute should also here be paid to the memory of Colonel Meadows Taylor. Endowed with talents of a high order, and gifted with indefatigable industry, he some fifty years since left Ireland for Bombay, as a clerk in a mercantile house. On his arrival

at his destination the house had failed, and the young adventurer's prospects were at an end. He soon, however, obtained a commission in the service of His Highness the Nizam, to whom he remained devotedly attached throughout his whole career. Exchanging his military for a civil appointment, he acquired an extensive knowledge of the people and languages of southern India; and as Judge, engineer, artist, and man of letters, he studied the laws, antiquities, geological features and literature of the country. In 1850 he was appointed to administer, during a long minority, the principality of the young Rajah of Shorapore, and during the mutiny in India he was able to hold his ground without requiring any military aid. His merits were highly appreciated by the British Government, and on his retirement from service he received from Her Majesty the honour of being made a Companion of the Star of India. His thorough knowledge and sympathetic appreciation of the ideas and manners of the native races of India were exhibited in several able and successful works of fiction, the scene of which was laid in that country.

Our Transactions and Proceedings contain several valuable contributions from his pen, amongst which may be named "a Catalogue of Indian Musical Instruments," "Description of the Contents of a Cairn at Hyat Nuggur in the Dekhan;" and "a Description of Cairns, Cromlechs, Kistvaens, and other Monuments in the Dekhan." In the numerous illustrations, from his original sketches, which accompany the last-mentioned memoir, there is evidence of his well-known artistic powers. Those who had the pleasure of knowing Colonel Taylor will long retain the impression made on them by the combined earnestness and gentleness of his character, and the singular charm of his conversation and manners. He was for several years a Member of the Council of the Academy.

The Report was adopted.

The following Grants, recommended by the Council out of the Parliamentary Grant for the preparation of Scientific Reports, were adopted:—

£50 to Rev. Professor Haughton, M. D., for Reports on the Tidal Constants of the Irish Coast; being the second instalment of the sum of £100 required for the expenses of calculations.

£10 to Dr. C. Bell for further Experiments on Pyrrol.

£50 to Dr. R. S. Ball towards the expenses to be incurred in the reduction of the recorded Observations of Jupiter's Satellites, preparatory to a re-discussion of their Theory.

£25 to Dr. Reynolds and Rev. Professor Haughton, M. D., for Experiments on the Dynamical Coefficients of Friction, at low velocities, between fluids and solids.

£25 to Rev. J. H. Jellett, B. D., for the Experiments on the Action of a Galvanic Current on a Beam of Polarized Light.

£40 to Dr. E. P. Wright, towards defraying the expenses of obtaining a series of drawings of some of the lower Algæ—the drawings to be the property of the Academy.

The Scrutineers having duly reported, the Vice-President, in the Chair, declared the following duly elected:—

PRESIDENT.

SIR ROBERT KANE, LL.D., F. R. S.

COUNCIL.

Committee of Science.

E. Perceval Wright, M.D., F.L.S; David Moore, Ph. D., F. L. S; John Casey, LL.D., F. R. S; Thomas Hayden, M. D; Rev. J. H. Jellett, B. D., S.F.T.C.D; Alexander Carte, M.D., F. L. S; William Archer, F. R. S; R. S. Ball, LL.D., F. R. S; J. E. Reynolds, M.D.; B. B. Stoney, M. A., C. E; Rev. S. Haughton, M. D., F. R. S.

Committee of Polite Literature and Antiquities.

J. K. Ingram, LL.D; W. J. O'Donnavan, LL.D; A. G. Richey, LL.D.; J. R. Garstin, LL.B., F. S. A.; Very Rev. Dr. Reeves, D.D.; Rev. Thaddeus O'Mahony, D.D.; Lord Talbot de Malahide, F.R.S.; Robert Atkinson, LL.D.; Thomas Drew, M. A., C. E.; S. Ferguson, LL.D.

The Scrutineers having reported, the Vice-President declared Señor Don Augusto Soromenho duly elected an Honorary Member.

Sir Robert Kane, the President elect, having taken the Chair—

The Ballot was then opened for the election of Officers; and the

Scrutineers having reported, the President declared the following duly elected:—

Treasurer.—John Ribton Garstin, LL.B.
Secretary of the Academy.—E. Perceval Wright, M. D.
Secretary of the Council.—J. Kells Ingram, LL.D.
Secretary of Foreign Correspondence.—William Archer, F. R. S.
Librarian.—Robert Atkinson, LL.D.
Clerk of the Academy.—Edward Clibborn, Esq.

The President, under his hand and seal, nominated the following as Vice-Presidents for the year 1877–78:—

Rev. J. H. Jellett, B. D; Samuel Ferguson, LL.D.; Thomas Hayden, M. D; Alexander Richey, LL.D.

The Academy then adjourned.

Monday Evening, April 9, 1877.

Sir Robert Kane, LL.D., F. R. S., President, in the Chair.

Rev. George Reade, M. A., F. A. Tarleton, LL.D., F.T.C.D., and Benjamin Williamson, A. M., F. T. C. D., were elected Members of the Academy.

Robert S. Ball. LL.D., Astronomer Royal of Ireland, read a letter from Professor Tait, "On the subject of Lagrange's Equations of Motion in Generalized Co-ordinates."

[This paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Robert S. Ball, LL.D., read "Observations on Comet I (1877) made at Dunsink."

[This paper will be published as Part 14 of Vol. XXVI. of the "Transactions."]

Denis Crofton, Esq., read a Paper "On the Brick with Babylonian Characters in the Museum of Trinity College, Dublin."

Professor O'Reilly exhibited a coloured drawing of a Meteorite seen by him near Dublin, on the evening of the 6th April, 1877, about 9 o'clock.

Monday Evening, April 23, 1877.

Sir Robert Kane, LL.D., F.R.S., President, in the Chair.

Dr. Foley and Dr. Tarleton signed the Roll and were admitted Members.

Robert S. Ball, LL.D., Astromoner Royal of Ireland, read a paper "On the Non-Euclidian Geometry."

C. R. C. Tichborne, Ph. D., read a Paper, "On the Dissociation of the Salts of Iron, and the formation of the Magnetic Oxide."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Edward Perceval Wright, M.D., read Notes "On the Echinoderms of the Seychelles."

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 2.]

Monday Evening, May 14, 1877.

Sir Robert Kane, LL.D., F.R.S., President, in the Chair.

Charles Lloyd, M.D., was elected Member of the Academy.

The Rev. Samuel Haughton, M.D., V.P., read a Paper, by the Rev. James Pearson, M.A., "On the Phenomena of the Tides as observed at Fleetwood, Lancashire.

[This Paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Denis Crofton, Esq., read a Paper "On a Slab, with a Cuneiform Inscription, in the Library of Trinity College, Dublin."

Dr. E. P. Wright exhibited some drawings, by Mr. L. Aldous, of a Sponge found at Mahè which exhibited heteromorphic zooids.

The Treasurer laid on the Table the estimate of the Income and Expenditure of the Academy for the current year.

Monday Evening, May 28, 1877.

Sir Robert Kane, LL.D., F.R.S., President, in the Chair.

Samuel Ferguson, LL.D., V.P., read a Paper "On Breton and Norse Rock Sculptures."

Monday Evening, June 11, 1877.

Sir Robert Kane, LL.D., F.R.S., President, in the Chair.

Rev. J. P. Mahaffy, M. A., F.T.C.D., read a Paper "On recent Excavations in Greece."

Professor A. Leith Adams read the first part of a Monograph "On Irish Fossil Mammals."

[This paper will appear in the "Proceedings," Second Series, Vol. III., Science, Part 1.]

Read the following letter from E. Perceval Wright, M.D., to the President, resigning the office of Secretary to the Academy.

"Trinity College, Dublin,
"*May* 25, 1877.

"Dear Mr. President,

"I have with regret come to the fixed conclusion that it is expedient that I should resign the office of Secretary to the Academy.

"The Editing of the Academy's Scientific Publications demands too great a sacrifice of my time, already too much occupied, and prevents me from devoting as much of it as I could wish to original research, and this might well serve as my excuse; but I confess that, in addition, I am not satisfied with the existing state of affairs in our body, and I believe that the nominal conduct thereof would, at the present crisis, be better in other hands.

"My election to the office I now resign I shall always regard as the highest reward the Members of the Academy could have given to my Scientific work, and for that reward I thank them. I have also to thank you Mr. President, for your unvarying courtesy, and to subscribe myself,

"Most faithfully yours,
"Edward Perceval Wright."

"Sir R. Kane, LL.D., F.R.S.
President, Royal Irish Academy."

It was unanimously Resolved—

"That the Academy receives with regret the resignation of Dr. Wright, and desires to place on record its sense of the valuable services rendered by him during his tenure of office, especially on the prompt publication in the Transactions and Proceedings of the Papers read before the Academy."

Monday Evening, June 25, 1877.

Sir Robert Kane, LL.D., F. R. S., President, in the Chair.

Dr. Robert S. Ball, F. R. S., Astromoner Royal for Ireland, was elected Secretary of the Academy, in place of Dr. E. Perceval Wright, F.L.S., resigned.

Mr. W. H. Baily, read a Paper "On Fossils of the Irish Coal District (Report)."

By permission of the Academy, Mr. William Plunkett, F.C.S., read a Report by himself and Launcelot Studdert, LL.D., "On the Solid and Gaseous Constituents of the Spa, at Mallow, Co. Cork."

[This Paper will appear in the "Proceedings," Vol. III., Second Series, Part 1, Science.]

By permission of the Academy, Mr. C. C. Hutchinson read a Paper by himself and Mr. A. H. M'Alpine, "On the Gaseous Constituents of the Vartry and Royal Canal waters."

[This Paper will appear in the "Proceedings," Vol. III., Second Series, Part 1, Science.]

By permission of the Academy, Professor Galloway read a Paper by Messrs. Reginald Laurence, and C. W. Reilly, "On the Albuminoid Matters, Alcohol and Phosphates, in the Burton Ales and Dublin Porter."

By permission of the Academy, Mr. Thomas Bayley read a Paper "On the Volumetric Estimation of Chromium."

[This Paper will appear in the "Proceedings," Vol. III., Second Series, Part 1, Science.]

By permission of the Academy, Mr. Thomas Bayley read a Paper "On the Peroxides of Cobalt and Nickel."

By permission of the Academy, a Paper by Mr. Henry Hatfield was read "On a Method for the detection of Cadmium in the presence of Copper."

The Treasurer laid on the Table the following Abstract of the Academy's Accounts for the year ending 31st of March, 1877, as Audited by the Rev. Samuel Haughton, M. D., and William Archer, F.R.S., Committee of Audit.

The Academy then adjourned until November.

GENERAL ABSTRACT OF THE ACCOUNT OF JOHN RIBTON

FOR THE YEAR ENDING

RECEIPTS.	For Special Purposes.	For General Purposes.	Total of each Class.
	£ s. d.	£ s. d.	£ s. d.
Balance from last Year,	2 1 6	43 15 7	45 17 1
FROM PARLIAMENTARY GRANTS:—			
Unappropriated:—"Old Grant,"	. . .	500 0 0	
Appropriated:—			
Preparation of Scientific Reports,	200 0 0		
Library,	200 0 0		
Researches in connexion with Celtic MSS.,	200 0 0		
Publication of ditto,	200 0 0		
Museum,	200 0 0		
Purchase of Treasure Trove,	100 0 0		
Illustration and Printing of "Transactions" and "Proceedings,"	200 0 0		
Opening the Academy in the evening,	137 8 0		1937 8 0
„ TRINITY COLLEGE GRANT towards reproduction of the MS. known as the Book of Leinster (on account of £700) making £420,	100 0 0	. . .	100 0 0
„ MEMBERS' PAYMENTS:—			
Entrance Fees,	. . .	73 10 0	
Annual Subscriptions,	. . .	344 8 0	
Life Membership Composition (*invested as opposite*),	90 6 0		508 4 0
„ PUBLICATIONS SOLD:—			
Transactions,	. . .	6 15 6	
Proceedings,	. . .	1 1 2	
„ Irish MSS. Series,	. . .	0 7 0	
Leabhar Breac,	. . .	18 5 0	
Leabhar na h-Uidhri,	. . .	6 15 0	
Photographs of Museum Objects,	. . .	0 11 0	
Museum Handbook,	. . .	1 3 0	
Museum Catalogue (*invested as opposite*),	5 15 6		40 13 2
„ INTEREST ON INVESTMENTS:—			
Life Composition—Consol. Stock,	. . .	73 8 8	
Cunningham Bequest—New 3 per cent. Stock (*see opposite*),	75 11 3		
Museum Catalogue—Bank of Ireland Stock (*see opposite*),	4 5 5		153 5 4
„ TEA FUND Subscriptions,	7 15 0		7 15 0
	£1723 2 8	1069 19 11	2793 2 7

I certify that the above account is correct, according to the best of my

for Auditors' Report

ACADEMY.

GARSTIN, TREASURER OF THE ROYAL IRISH ACADEMY,

31ST OF MARCH, 1877.

PAYMENTS.	From Funds appropriated for Special Purposes. £ s. d.	From Funds available for General Purposes. £ s. d.	Total of each Class. £ s. d.
FOR SCIENTIFIC AND LITERARY PURPOSES:—			
Polite Literature and Antiquity Objects,	. . .	. . .	
Scientific Reports,	200 0 0		
Library,	200 0 0	61 19 0	
Irish Scribe, &c.,	200 0 0	0 8 5	
" (including Lithographing of Leabhar Breac, and Printing Felire of Aengus, Part I.),	200 0 0		
Museum,	200 0 0	30 11 3	
Treasure Trove	100 0 0	36 0 6	
Transactions and Proceedings,	200 0 0	196 13 4	
Opening the Academy in the evening,	137 8 0		
Cunningham Prizes,	20 0 0		
Book of Leinster,	93 12 0		1849 12 6
" ESTABLISHMENT CHARGES:—			
Salaries,	. . .	404 0 0	
Wages and Liveries,	. . .	208 5 6	
Fuel,	. . .	21 15 0	
Insurance, Taxes, and Law,	. . .	8 2 6	
Stationery,	. . .	10 9 0	
Printing (Miscellaneous),	. . .	43 13 11	
Postage,	. . .	27 8 5	
Freights, Incidentals, and Contingencies,	. . .	30 17 7	754 11 11
" INVESTMENTS (CAPITAL):—			

	Stock Bought. £	s.	d.	Description.	Total Stock. £	s.	d.		
Life Membership Compositions,	93	2	1	Consol. Stock,	2572	0	2	90 6 0	
Cunningham Bequest Interest, Balance,	58	0	0	New 3 per Cents,	2618	9	5	55 11 3	
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